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EFFECTS OF SAMPLE SIZE AND AGEING ERROR ON ESTIMATES OF SUSTAINED YIELD

By:

Lewis G. Coggins, Jr., B.S.

A thesis presented to the Faculty
of the University of Alaska Fairbanks
in partial fulfillment of the requirements
for the degree of

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ABSTRACT

A Monte Carlo simulation model of an exploited age-structured fish population was constructed to evaluate the effects of sampling and ageing the catch on estimates of population parameters from catch-age analysis with auxiliary information and resultant estimates of sustained yield. A factorial experimental design was used where input parameters were varied among: small (100), medium (300) and large (900) catch sample sizes; high and low levels of ageing precision; and a range of ageing biases. Ageing bias and precision had dramatic effects on estimated sustained yield: positive ageing bias and ageing imprecision generally caused under-estimation of sustained yield, while negative ageing bias caused over-estimation of sustained yield. The multiple reader/reading ageing scenarios designed to mitigate ageing error were able to reduce the affects of ageing imprecision, but were unable to alleviate the problems associated with ageing bias. The simulation model can be modified for a variety of recreational fish populations; a diskette and user manual are available.

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INTRODUCTION

Fisheries management should be rooted in sound knowledge of all factors contributing to the dynamics of the exploited fish population (Summerfelt 1986). These factors include, but are not limited to, understanding the basic life history of the species, exploitation patterns of the prosecuting fisheries, and environmental factors which influence the abundance and distribution of the species. Once these basic biological parameters have been uncovered, various mathematical constructs to model population dynamics exist which can be used by fisheries researchers and managers to define patterns and levels of exploitation to achieve management objectives.

One model of particular utility in estimating sustained yield was proposed by Quinn and Szarzi (1993). Quinn and Szarzi's model (QS) assumes a constant fishing mortality rate harvest policy and relies on the results of catch-age analysis with auxiliary information (Deriso et al. 1985, 1989) to generate estimates of sustained fishing mortality and subsequent estimates of sustained yield in either a Leslie matrix (Getz and Haight 1989) or a per-recruit (Sissenwine and Shepard 1987, Fletcher 1987) estimation format.

The concept of fisheries management to achieve sustained yield is widely accepted but rarely explicitly defined. Various management objectives can result in a sustained yield policy but have different implications with regard to the productivity of the stock, the expected age composition of the catch, or many other population parameters. This study addressed two of the many management objectives which result in sustained yield. They are: (1) the sustained yield (SY_{ST}) that results from applying a constant fishing mortality rate (F_{ST}) that tends to force the population to a steady long term equilibrium abundance and age composition, and (2) the sustained yield (SY_{m+}) that results from applying a constant fishing mortality rate (F_{m+}) to maximize the catch of fully mature fish.

These management objectives stem from somewhat nebulous goals sometimes defined for sport fisheries. For instance, if "Catchalot Creek" were to be managed for the goal of "maintaining size and age composition of rainbow trout", then having the specific objective of applying the constant fishing mortality rate F_{ST} would be a way of achieving the goal. Similarly, if the goal were to "manage Catchalot Creek as a trophy rainbow trout fishery" then applying F_{m+} would achieve the goal. Although well meaning, these types of nebulous goals require translation into a set of specific procedures and objectives that are both quantifiable and defensible. The QS model provides a structure to estimate the level of fishing mortality and resultant sustained yield associated with a specific management objective.

Catch-age analysis with auxiliary information (CAGEAN) is a cornerstone to the QS model. CAGEAN belongs to a class of models generally known as age-structured stock assessment models (ASA; Megrey 1989). Though part of a long history of development beginning with fundamental contributions by Baranov (1918) and Derzhavin (1922), present day state-of-the-art models were contributed by Deriso et al. (1985, 1989; CAGEAN) and Methot (1989; stock synthesis model). Each of these models was in turn based on earlier work by Doubleday (1976) in the case of CAGEAN, and Fournier and Archibald (1982) in the case of the stock synthesis model. These models are fundamentally different in the assumed error structure around the catch-at-age data and the procedure used to estimate model parameters. CAGEAN assumes lognormally distributed error around the catch-at-age data and uses a non-linear least squares procedure for parameter estimation. Stock synthesis assumes a multinomial error structure around the catch-at-age data and uses a multinomial maximum likelihood procedure for parameter estimation.

Like many complex age-structured analyses, the QS model relies on catch-at-age data which are subject to introduced error from sampling and age determination (ageing error). Ageing error occurs when a reader responsible for estimating the age of a structure assigns an age, called an age reading, that is different from the true age. Ageing error can occur as a result of ageing imprecision, defined as the variability among multiple readings of a single structure, as a result of ageing bias, defined as the difference between the expected value of the observed age and the true age, or as a result of a combination of imprecision and bias (Kimura and Lyons 1991).

Notable studies by Beamish and Fournier (1981) and Chang (1982) have addressed the concept of ageing precision by developing indices of precision (or imprecision) such as the average percent agreement or the coefficient of variation. These indices can be applied to multiple readings by a single reader or single readings by multiple readers resulting in measures of within- or between-reader precision, respectively. Within-reader precision is sometimes used as a measure of an individual's skill as a reader, while between-reader precision is sometimes used to characterize the inherent "ageability" of a species or the applicability of ageing criteria (Kimura and Lyons 1991). Hoenig et al. (1994) also propose a procedure for testing the precision of multiple age assignments which contains the additional property of testing for bias between readers or ageing methods. This is accomplished through the use of a test of symmetry whereby systematic differences between multiple readings can be detected.

Measuring ageing bias or accuracy is significantly more difficult than measuring precision in that the true age of a structure must be known through some type of validation. Beamish and McFarlane (1983) surveyed the literature and found that of 500 studies published between 1907 and 1980, only 65% even mention validation and that only 3% successfully validated the ageing technique.

The effects of sample size and ageing error on model estimates have been investigated by various researchers in both ASA type models and in yield-per-recruit or biomass based models. However, the effect of sample size and ageing error has not been examined as related to sustained yield estimates from a combined ASA type model and Leslie matrix or yield-per-recruit model like the QS model. The intent of this paper is to investigate the performance of the QS model given various sample sizes and types of ageing error.

1.1 Project Objective and Tasks

Objective
The primary objective of this study was to:

> Evaluate the bias and variability in estimates of projected abundance, sustained fishing mortality, and resultant sustained yield from the QS model as a function of sample size and ageing error under two management objectives: (1) SY_{ST}, and (2) SY_{m+}.

Tasks
To achieve the objective defined above, the following tasks were accomplished:

(1) The development of computer software (program AGEERR) designed to evaluate the effect of sample size and ageing error on estimates of sustained yield of an exploited age structured fish population using the sustained yield estimation method of Quinn and Szarzi (1993).

(2) Use program AGEERR to evaluate the effects of ageing error and sample size when estimating the sustained yield of the mainstem Gulkana River Arctic grayling (*Thymallus arcticus*) population studied extensively by Bosch (1995).

METHODS

A FORTRAN computer program was constructed to model an exploited age-structured fish population and evaluate the effect of the processes of sampling and ageing the catch on estimates of population parameters from catch-age analysis and resultant estimates of sustained yield. The program (AGEERR) contains four procedures: (1) generation of an exploited age-structured fish population with associated true catch- and abundance-at-age; (2) construction of observed catch-at-age data by incorporating measurement error due to sampling, ageing error, and variability in the total catch; (3) estimation of population parameters through catch-age analysis with auxiliary information based on observed catch-at-age and auxiliary observed survey data; and (4) estimation of sustained yield using the population parameter estimates from catch-age analysis with auxiliary information. Descriptions of the formulations of each of the procedures as well as the methods used to conduct the case study using Gulkana River grayling are presented in the following sections. Appendices A, B, and C contain a users manual for program AGEERR.

2.1 Generation of the True Population

In order to simulate the population under investigation, a time series of true catch- and abundance-at-age was generated using the typical recursion and Baranov catch equations (Baranov 1918). The relevant formulae are given as:

$$N_{a+1,t+1} = N_{a,t}e^{-Z_{a,t}} \tag{1}$$

$$N_{A+,t+1} = N_{(A+)-1,t}e^{-Z_{(A+)-1,t}} + N_{A+,t}e^{-Z_{A+,t}} \tag{2}$$

$$C_{a,t} = \mu_{a,t} N_{a,t} \tag{3}$$

$$\mu_{a,t} = \frac{F_{a,t}}{Z_{a,t}} \left[1 - e^{-Z_{a,t}}\right] \tag{4}$$

$$Z_{a,t} = F_{a,t} + M \tag{5}$$

$$F_{a,t} = s_a f_t \quad , \tag{6}$$

where $N_{a,t}$ is the true abundance of age a fish in year t, $Z_{a,t}$ is the total instantaneous mortality rate, $A+$ is an aggregate plus age group, $C_{a,t}$ is the true catch, $\mu_{a,t}$ is the true exploitation rate, M is the true natural mortality rate, $F_{a,t}$ is the true fishing mortality rate, s_a is the true gear selectivity coefficient, and f_t is the true full recruitment fishing mortality (Deriso et al. 1985, 1989). Equation 2 is a generalization of equation 1 appropriate when an aggregate age class ($A+$) is used. The common assumption of separable fishing mortality (Doubleday 1976, Deriso et al. 1985, Fournier and Archibald 1982, Pope 1977, Pope and Shepherd 1982) is implicit in equation 6.

2.2 Observed Catch-at-Age Data

Observed catch-at-age was calculated as the product of the observed catch-age proportion and the observed total catch as:

$$C'_{a,t} = C'_t \, \theta'_{a,t} \quad , \tag{7}$$

where $C'_{a,t}$ is the observed catch of age a fish during year t, C'_t is the observed total catch, and $\theta'_{a,t}$ is the observed catch-age proportion.

Variability was included in both the observed total catch and the observed catch-age composition. To mimic the uncertainty in the estimates of total catch, it was assumed that the observed total catch followed a normal distribution with expected value equal to the true total catch and a constant coefficient of variation (cv_C):

$$C'_t \sim N\left(C_t, \sigma_{C(t)}{}^2\right) \tag{8}$$

$$\sigma_{C(t)}{}^2 = \left(cv_C C_t\right)^2 \quad , \tag{9}$$

where C_t is the true total catch in year t, $\sigma_{C(t)}{}^2$ is the variance of the observed total catch, and cv_C is the constant coefficient of variation of the observed catch. This formulation allows one to specify the precision of the observed catch by simply an assumed constant coefficient of variation.

The observed age composition of the catch was generated by sampling and ageing the true catch and incorporating error in the ageing process. Catch sampling was conducted randomly without replacement such that the probability of selecting a fish of a particular age was equal to the true proportion of that age remaining in the catch.

Modeling Ageing Error

A common technique in ageing labs is to assign an age to a structure (e.g. scales, otoliths, fin rays) based on the central tendency of multiple readings of a single structure (Chilton and Stocker 1987, Pikitich and Demory 1988, Booth et al. 1995). This is performed to reduce ageing error by improving ageing precision. Another common technique is to define an aggregate "plus" group when it is apparent that ageing error reaches unacceptable levels above some true age. This amounts to assigning an age of A+ when a structure is of observed age A or older.

In developing the ageing error portion of the simulation, it was recognized after consideration of current literature and ageing techniques that the model should contain the following four attributes: (1) the use of multiple readers with different abilities with regard to ageing precision and bias; (2) the ability to allow specification of the magnitude of ageing precision and bias; (3) the ability to allow comparisons of multiple readings to determine observed age; and (4) the ability to allow for the incorporation of a plus group.

Modeling Reader Types

The simulation uses multiple reader types to generate multiple distributions of ageing error and to allow comparisons among readers of differing abilities. Reader 0 (R0) is a perfect reader without ageing error of any kind. Reader 1 (R1) is characterized as the ideal "real life" reader being both accurate (no bias) and precise (low variability). Reader 2 (R2) is accurate but with greater imprecision than reader R1. Reader 3 (R3) is inaccurate but precise. Reader 4 (R4) is inaccurate and imprecise. Readers R1 and R3 have identical constant and low imprecision. Readers R2 and R4 have identical variable imprecision as a function of true age which is defined to always be greater than or equal to the constant imprecision of readers R1 and R3. Statistical characterizations of each reader are given below:

R0 $a = b$

R1 $a \sim \mathrm{N}(b, \sigma)$

R2 $a \sim \mathrm{N}(b, \sigma(b)), \sigma(b) \geq \sigma$

R3 $a \sim \mathrm{N}(b+c, \sigma)$

R4 $a \sim N(b+c, \sigma(b))$,

where a is the observed age, b is the true age, c is the systematic bias of the inaccurate reader, σ is a constant standard deviation, and $\sigma(b)$ is standard deviation as a function of true age.

Classification matrices were used to specify ageing precision for each reader type. Richards et al. (1992) present a formulation for constructing a classification matrix which is central to modeling ageing error in this study. This technique was employed as follows:

$$\Phi = (\sigma_r, \sigma_A, \alpha) \tag{10}$$

$$\sigma(b) = \begin{cases} \sigma_r + (\sigma_A - \sigma_r)\dfrac{1-e^{-\alpha(b-r)}}{1-e^{-\alpha(A-r)}}; & \alpha \neq 0 \\ \sigma_r + (\sigma_A - \sigma_r)\dfrac{b-r}{A-r}; & \alpha = 0 \end{cases} \tag{11}$$

$$\chi_{ab}(\Phi) = \frac{1}{\sqrt{2\pi}\,\sigma(b)} e^{-\frac{1}{2}\left[\frac{a-b}{\sigma(b)}\right]^2} \tag{12}$$

$$q(a|b,\Phi) = \frac{\chi_{ab}(\Phi)}{\sum_{a=r}^{A} \chi_{ab}(\Phi)} \tag{13}$$

$$\mathbf{Q}(\Phi) = \left[q(a|b,\Phi)\right]_{a=r,r+1,\ldots,A} \; . \tag{14}$$

The preceding five equations define the classification matrix [$\mathbf{Q}(\Phi)$]. The elements of the classification matrix are the probabilities that a fish of true age b is assigned an observed age a. Equation 10 defines Φ (the parameter vector of the classification matrix) made up of σ_r and σ_A (the lower and upper bounds of $\sigma(b)$ corresponding to the standard deviation at the recruitment and oldest ages), and a parameter α that governs the non-linearity of $\sigma(b)$. Equation 11 defines $\sigma(b)$ (the standard deviation of observed age a given true age b) as a function of σ_r, σ_A, α, r (recruit age), and A (the oldest true age). The chi matrix $[\chi_{ab}(\Phi)]$, defined by the density function in equation 12, has column vectors corresponding to a discrete normal probability function of observed age a given true age b. The elements of the classification matrix $[q(a|b,\Phi)]$ are weighted in equation 13 such that the sum of each column vector of the classification matrix is equal to one. Finally, equation 14 explicitly defines $q(a|b,\Phi)$ as the elements of the classification matrix $\mathbf{Q}(\Phi)$. For readers R1 and R3, $\sigma(b)$ is replaced with the constant σ.

There are two assumptions regarding the formulation of the classification matrix. The first assumption is: $q(b|b,\Phi) \geq q(a|b,\Phi) \quad a \neq b$. This is the "modal" probability assumption and asserts that fish of true age b are assigned an observed age a equal to b with higher probability than any other observed age. The second assumption is: $\sum_{a=r}^{A} q(a|b,\Phi) = 1$ for each b. This assumption assures that the probabilities of all the possible observed ages for any true age sum to one.

Although the modal assumption assures that observed age a equals true age b with highest probability, observed age a cannot be said to be unbiased. This is because the observed age must lie within the lifespan of the species (or the true age range recruited to a fishery) and truncation of the observed age distribution occurs near the bounds of the true age range. For example, if the youngest fish of a given species ever captured had a true age of 3, the probability of assigning an observed age $a < 3$ would be zero. Therefore, the age of fish with a true age of 3 would tend to be over-estimated. A similar argument can be made regarding the under-estimation of the age of older fish.

Therefore the simulation also allowed for the inclusion of systematic bias by specifying a constant bias c. This was accomplished by adding the bias after the true age was modified with imprecision so that the imprecision was specified based on the true age. A negative value of the bias c caused under-ageing of a structure and a positive value caused over-ageing. It should be noted however, that the bias will not cause the observed age to traverse the true age range. For example, a bias of -1 will still result in an observed age no smaller than 2 if the lower bound of true age is equal to 2.

Modeling the Ageing Process

The simulation incorporated 4 scenarios to model the types of procedures commonly used in ageing labs to help mitigate within- and between-reader precision as well as between-reader bias, and hence ageing error. Scenario 1 portrays the most common ageing procedure of employing a single reader to provide a single reading of each structure. The second scenario also employs a single reader but each structure is read three times. The third scenario employs two readers each reading the structure a single time. Finally, the fourth scenario employs two readers who both read the structure 3 times.

Given multiple readings of a structure, a final age had to be assigned (Appendix C2). Final observed age for a structure in scenario 1 was assigned as the single reading of each structure. In the second scenario, the final observed age was assigned as a result of three intermediate readings. These intermediate readings were treated two ways resulting in scenarios 2a and 2b. In scenario 2a, the final observed age was assigned as the mode of the three intermediate readings; if no mode existed, the structure was removed from the sample. In scenario 2b, the final observed age was assigned as the modal age; if no mode existed, the final observed age was assigned as the median of the intermediate readings. The third scenario employed two readers resulting in two intermediate readings. If the two intermediate readings were equal, then the final observed age was assigned as the agreed age. If the intermediate readings were not equal, then the final observed age was assigned the final observed age of an "expert" reader. Since the R1 reader is the ideal real life reader, the observed age from scenario 1 reader R1 was used as the expert's age determination. One of the applications of scenario 3 employed two R1 type readers. In this situation, when the two readers disagreed, neither was considered "more expert" so the rounded mean of the intermediate ages was used as final observed age. Scenario 4 was a combination of scenarios 2 and 3 and like scenario 2 consisted of two sub-scenarios. Scenario 4a compared the modes of three replicate readings by two readers to determine final observed age. If both readers had intermediate readings resulting in a mode and the modes among the two readers agreed, then final observed age was the agreed age. If both readers produced a modal intermediate age but the modes were not equal, final observed age was the expert's observed age. If either of the readers failed to produce a modal age, the structure was removed from the sample. Scenario 4b was similar except that the median of the intermediate readings was used in the circumstance that there was not a modal intermediate age. Final observed age was then determined in an identical fashion to scenario 4a.

Table 2.1 displays which reader types were employed in each scenario. The first scenario employed all five reader types. Scenario 2 employed only readers R1 - R4 since replicate readings among the perfect reader would be identical. Scenario 3 employed readers R1 - R4, but no combinations of reader R1 with other reader types were used since disagreements would be resolved by an R1 reader. Finally, the fourth scenario employed only readers R1 and R4 in order to examine the best and worst readers and to minimize comparisons. Of the 23 estimated age compositions, 22 are constructed with ageing error and one (scenario 1, reader R0) is constructed with no error.

2.3 Catch-Age Analysis with Auxiliary Information

Catch-age analysis with auxiliary information was performed using a variant of program CAGEAN (Deriso et al. 1985) called program CAGEM. Program CAGEM assumes a multinomial-like measurement error structure appropriate given ageing error in the observed catch-at-age data. The relevant formulae for the objective function for

Table 2.1 Distribution of reader types within scenarios.

n = number of readers
m = number of readings

Scenario	Reader Types
1	R0
n=1	R1
m=1	R2
	R3
	R4
2a & 2b	R1
n=1	R2
m=3	R3
	R4
3	R1 vs R1
n=2	R2 vs R2
m=1	R3 vs R3
	R4 vs R4
	R2 vs R3
	R3 vs R4
4a & 4b	R1 vs R1
n=2	R4 vs R4
m=3	

parameter estimation given the multinomial measurement error structure and survey exploitable abundance are:

$$\min\left\{\sum_{a,t}\frac{\left[C'_{a,t}-\hat{C}_{a,t}\right]^2}{\hat{C}_{a,t}}+\lambda_s\left[\ln(SUR_t)-\ln\left(\hat{EN}_t\right)\right]^2\right\} \tag{15}$$

$$\hat{EN}_t=\sum_a \hat{N}_{a,t}\hat{s}_a \quad , \tag{16}$$

where $C'_{a,t}$ is the observed catch of age a fish in year t, $\hat{C}_{a,t}$ is the estimated catch, SUR_t is the total exploitable abundance from an independent survey, $\hat{EN}_t$ is the estimated total exploitable abundance, λ_s is a weighting factor for the auxiliary survey information, $\hat{N}_{a,t}$ is the estimated abundance, and $\hat{s}_a$ is the estimated selectivity-at-age. The catch $\hat{C}_{a,t}$, abundance $\hat{N}_{a,t}$, and selectivity $\hat{s}_a$ were estimated within program CAGEM using equations (1) - (6) such that a hat (^) signifies that it is an estimated parameter.

For the simulation model, variability in the survey exploitable abundance was specified with a coefficient of variation as:

$$\mathrm{SUR}_t \sim N\left(EN_t, \sigma_{S(t)}{}^2\right) \tag{17}$$

$$\sigma_{S(t)}{}^2 = \left(cv_S\ EN_t\right)^2 \quad , \tag{18}$$

where EN_t is the true exploitable abundance in year t, $\sigma_{S(t)}{}^2$ is the variance of the survey total exploitable abundance around the true exploitable abundance, and cv_S is the assumed constant coefficient of variation of the survey total exploitable abundance.

2.4 Estimation of Sustained Yield

Sustained yield was estimated according to two separate management objectives, SY_{ST} and SY_{m+}. Both assume that the population is exploited with a constant fishing mortality rate and that early life survival, natural mortality and fecundity-at-age are constant. The first objective seeks to find the fishing mortality (F_{ST}) which will take the population to its steady long term equilibrium abundance and age composition. This was accomplished by finding the fishing mortality (F_{ST}) which causes the net reproductive value of an *r* year old fish (age at recruitment to the fishery) to equal 1. A simple interpretation of this equilibrium condition is that every fish recruited to the fishery at age *r* must on average produce 1 recruit at age *r*. In the course of finding F_{ST}, it is necessary to estimate early life survival. This was accomplished by taking the mean of the annual estimates of early life survival since each annual estimate of early life survival is equally likely. Once F_{ST} was found, the sustained yield (SY_{ST}) in the year following the last year of the analysis was estimated. The relevant formulae for the estimation of F_{ST} and SY_{ST} are:

$$\hat{N}_{0,t} = \sum_{a=r}^{A} \hat{N}_{a,t} fec_a \tag{19}$$

$$l_{r,t} = \hat{N}_{r,t+r} / \hat{N}_{0,t} \tag{20}$$

$$\bar{l}_r = \sum_{t=1}^{n} l_{r,t} \bigg/ n \tag{21}$$

$$l_a = \bar{l}_r \prod_{x=1}^{a-1} S_x \tag{22}$$

$$S_x = \exp(-Z_x)\ , \text{ for } x \geq r \tag{23}$$

$$R_0 = \sum_{a=r}^{A} fec_a l_a \quad , \tag{24}$$

where $\hat{N}_{0,t}$ is the estimated number of eggs produced in year t, fec_a is the net fecundity of an age a fish, $\bar{l}_r$ is the average early life survival, $l_{r,t}$ is the early life survival from brood year t, $\hat{N}_{r,t+r}$ is the estimated abundance of recruitment age fish in year $t+r$, l_a is the survival from an egg to age a, S_x is the survival fraction-at-age, and R_0 is net reproductive value of an r year old fish.

The estimated catch (SY_{ST}) in the year following the last year of the analysis is given as:

$$SY_{ST} = \sum_a \hat{\mu}_a \hat{N}_{a,t+1} \tag{25}$$

$$\hat{\mu}_a = \frac{F_{ST}\hat{s}_a}{F_{ST}\hat{s}_a + M}\left[1 - \exp\left(-F_{ST}\hat{s}_a - M\right)\right] \tag{26}$$

$$\hat{N}_{a,t+1} = \begin{cases} \hat{N}_{0,t+1-r}\bar{l}_r \,, \text{ if } a = r \\ \hat{N}_{a-1,t}e^{-\hat{Z}_{a-1,t}} \,, \text{ if } r < a < A+ \\ \hat{N}_{(A+)-1,t}e^{-\hat{Z}_{(A+)-1,t}} + \hat{N}_{A+,t}e^{-\hat{Z}_{A+,t}} \,, \text{ if } a = A+ \end{cases} , \tag{27}$$

where F_{ST} is the fishing mortality such that $R_0 = 1$.

Equation 19 estimates the number of eggs produced in year t as the product of abundance and net fecundity. Equation 20 estimates the early life survival by finding the ratio of the number of recruits in year $t+r$ to the number of eggs produced in year t. The average early life survival is given by equation 21. The survival from an egg to age a is defined in equation 22 as the product of early life survival and the survival fraction-at-each age to age a. Equation 24 defines the net reproductive value as the product of net fecundity-at-age and survival to age a. Finally, equation 25 estimates the sustained yield in the year following the last year of the analysis as the product of the exploitation rate given F_{ST} (equation 26) and the projected abundance (equation 27) based on the average early life survival ($\bar{l}_r$).

The second objective seeks to find the fishing mortality (F_{m+}) which will produce the largest catch of age m (typically m is age of full maturity) and older fish on a per-recruit basis (Sissenwine and Shepherd 1987, Fletcher 1987). As with F_{ST} above, F_{m+} is used to estimate the sustained yield (SY_{m+}) in the year following the last year of the analysis. The relevant formulae are:

$$C_{m+}/N_r = \sum_{a=m}^{A} \hat{\mu}_a \hat{L}_a \tag{28}$$

$$\hat{L}_a = \prod_{x=r}^{a-1} \hat{S}_x \quad , \tag{29}$$

where C_{m+}/N_r catch-per-recruit, and A is the oldest true age recruited to the fishery, $\hat{L}_a$ is the survival from age r to age a, and $\hat{\mu}_a$ is the exploitation rate given F_{m+} estimated from equation (26) with F_{m+} in place of F_{ST}.

The estimated catch (SY_{m+}) in the year following the last year of the analysis is given by equations (25) - (27) with F_{m+} in place of F_{ST} where F_{m+} is the fishing mortality that maximizes catch-per-recruit.

If the catch-age analysis incorporates a plus age group, an additional parameter, fecundity of the plus age group, is necessary in order to estimate the sustained yield. A logical means of estimating this fecundity is to use a weighted average of the fecundity of the ages making up the plus group with weights equal to 1, exp(-Z), exp(-2Z), exp(-3Z),... with estimates of fishing mortality equal to the average fishing mortality applied to the modeled population as:

$$Z = \overline{F} + M \tag{30}$$

$$\overline{F} = \frac{\sum_{x=1}^{t} F_x}{t} \quad . \tag{31}$$

This weighting strategy will discount the fecundity contribution of the older ages proportional to their relative abundance in the plus group.

2.5 Gulkana River Grayling Case Study

Experimental Design

To examine the effect of sample size and ageing error on estimates of sustained yield, program AGEERR was used to simulate the estimation of sustained yield for the mainstem Gulkana River Arctic grayling (*Thymallus arcticus*) population conducted by Bosch (1995). The population parameters estimated by Bosch were used to simulate the population among 24 runs of program AGEERR performed according to a factorial design with 3 sample sizes and 8 levels of ageing error described below (Table 2.2). Each of the program AGEERR runs used 1000 Monte Carlo replications.

Table 2.2 Program AGEERR input parameters for each simulation run.

sample size	σ_I	σ_A	α	σ	bias (c)	CV_{survey}	CV_{catch}	λ_α	Age at full selectivity	Age at full maturity (m)	Pooling Age
100	0.4082	0.6412	-0.2542	0.4082	-1	0.22	0.05	1300	3	6	7
100	0.4082	0.6412	-0.2542	0.4082	-2	0.22	0.05	1300	3	6	7
100	0.4082	0.6412	-0.2542	0.4082	1	0.22	0.05	1300	3	6	7
100	0.4082	0.6412	-0.2542	0.4082	2	0.22	0.05	1300	3	6	7
100	0.8164	1.2823	-0.2542	0.8164	-1	0.22	0.05	1300	3	6	7
100	0.8164	1.2823	-0.2542	0.8164	-2	0.22	0.05	1300	3	6	7
100	0.8164	1.2823	-0.2542	0.8164	1	0.22	0.05	1300	3	6	7
100	0.8164	1.2823	-0.2542	0.8164	2	0.22	0.05	1300	3	6	7
300	0.4082	0.6412	-0.2542	0.4082	-1	0.22	0.05	1300	3	6	7
300	0.4082	0.6412	-0.2542	0.4082	-2	0.22	0.05	1300	3	6	7
300	0.4082	0.6412	-0.2542	0.4082	1	0.22	0.05	1300	3	6	7
300	0.4082	0.6412	-0.2542	0.4082	2	0.22	0.05	1300	3	6	7
300	0.8164	1.2823	-0.2542	0.8164	-1	0.22	0.05	1300	3	6	7
300	0.8164	1.2823	-0.2542	0.8164	-2	0.22	0.05	1300	3	6	7
300	0.8164	1.2823	-0.2542	0.8164	1	0.22	0.05	1300	3	6	7
300	0.8164	1.2823	-0.2542	0.8164	2	0.22	0.05	1300	3	6	7
900	0.4082	0.6412	-0.2542	0.4082	-1	0.22	0.05	1300	3	6	7
900	0.4082	0.6412	-0.2542	0.4082	-2	0.22	0.05	1300	3	6	7
900	0.4082	0.6412	-0.2542	0.4082	1	0.22	0.05	1300	3	6	7
900	0.4082	0.6412	-0.2542	0.4082	2	0.22	0.05	1300	3	6	7
900	0.8164	1.2823	-0.2542	0.8164	-1	0.22	0.05	1300	3	6	7
900	0.8164	1.2823	-0.2542	0.8164	-2	0.22	0.05	1300	3	6	7
900	0.8164	1.2823	-0.2542	0.8164	1	0.22	0.05	1300	3	6	7
900	0.8164	1.2823	-0.2542	0.8164	2	0.22	0.05	1300	3	6	7

Runs 1-4, 9-12, and 17-20 are the high precision case.
Runs 5-8, 13-16, and 21-24 are the low precision case.

Gulkana River Grayling Population Parameters

Bosch estimated sustained fishing mortality and yield (F_{ST}, F_{m+}, SY_{ST}, and SY_{m+}) using the QS model. The sustained yield, sustained fishing mortality, population parameters, and the fecundity-at-age estimated by Bosch are reported in Table 2.3. Note that since Bosch used an aggregate age group of 7+ but considered the population to have a longevity of age 10, the plus group abundance was apportioned to the contributing age classes and the fecundity of the plus group was estimated. To calculate the 7+ fecundity, the weighting scheme described above was used resulting in a 7+ fecundity of 4140. To apportion the 7+ abundance in the first year to ages 7, 8, 9, and 10, an average exponential decay similar to the fecundity calculation was used.

Let:

$$N(a,1986) = N(7+,1986)\frac{e^{-(a-6)Z}}{\sum_{i=1}^{4} e^{-iZ}} \quad , \tag{32}$$

where $Z = \overline{F} + M$ and $\overline{F}$ is the average fishing mortality experienced by the population during 1986-1991.

The cv_S was set equal to the average annual coefficient of variation of the exploitable abundance estimates from mark-recapture studies of Gulkana River Arctic grayling (Bosch 1995). The values range from 15% to 40% with an average of 22%. An estimate of cv_C was not available so an arbitrary value of 5% was used.

Table 2.3 Estimated population parameters for the mainstem Gulkana River grayling stock either contained in, or estimated from, Bosch (1995).

	SY_{ST}	SY_{6+}
Sustained Yield	29,867	17,019

	F_{ST}[1]	F_{6+}
Sustained Fishing Mortality	0.402	0.212

Projected Abundance in 1992	153,133
Natural Mortality	**0.3**[2]

Fishing Mortality

Year	f_t
1986	**0.330**
1987	**0.232**
1988	**0.190**
1989	**0.154**
1990	**0.059**
1991	**0.081**

Abundance

	AGE									
Year	2	3	4	5	6	7+	7	8	9	10
1986	**34,253**	**30,311**	**23,874**	**4,540**	**2,331**	81	**36**	**22**	**14**	**9**
1987	**41,271**	23,852	16,127	12,702	2,416	1,283				
1988	**22,390**	29,274	14,007	9,471	7,459	2,172				
1989	**46,004**	16,010	17,946	8,587	5,806	5,905				
1990	**90,218**	33,117	10,175	11,405	5,457	7,443				
1991	**16,940**	66,100	23,125	7,105	7,964	9,008				

	AGE					
	2	3	4	5	6	7+
Selectivity	**0.187**	**1**	**1**	**1**	**1**	**1**

	AGE									
	2	3	4	5	6	7+	7	8	9	10
Net Fecundity	**124**	**469**	**975**	**1,616**	**2,739**	**4,140**	**3,463**	**4,192**	**4,888**	**5,613**

[1] Bosch (1995) reported $F_{ST} = 0.6908$ due to an error in his estimation spreadsheet.
[2] Bolded parameters are required by program AGEERR.

Specifying Sample Size

Three sample sizes (100, 300, and 900) were used to evaluate the effect of sample size on the sustained yield estimates from the QS model. The samples sizes were picked to generally reflect sampling rates which would be below acceptable limits, at acceptable limits, or above acceptable limits to achieve age class proportions estimates that were within 5% of the true value with 80% confidence (d=0.05, α=0.20; Thompson 1987, Fournier 1983, Quinn et al. 1983).

Specifying Grayling Ageing Error

To specify ageing precision germane to the R2 and R4 type readers ($\sigma(b)$) in the low precision case, a data set was constructed containing estimated ages of scales collected from grayling before and after a known time-at-large. These data were from grayling collected at Fielding Lake, and the Chatanika, Chena, Salcha, and Gulkana Rivers (Merritt and Fleming 1991, Bosch 1995). Because none of these readings were validated, it was assumed that the first reading was correct and the expected age of the second reading was the sum of the first reading and the time-at-large. The data were then sorted by expected age and the standard deviation of observed age was estimated for each expected age class (Appendix B16). Both formulations of equation 11 were then fitted to the data (Appendix B17). Although the three parameter case was not found to have a significantly better fit than the two parameter case using an F-test proposed by Schnute (1981; p=0.57), the three parameter case was used throughout the simulations so that precision of readers R2 and R4 could be specified non-linearly. Although the age range in this analysis ranged from age 3 to age 10, the estimated σ_r was used throughout the simulations to describe the ageing imprecision of recruit age fish. The constant ageing precision of readers R1 and R3 (σ) in the low precision case was set equal to the parameter estimate for σ_r.

Two levels of ageing precision and 4 levels of bias were used to specify ageing error in the simulations (Table 2.2). As described above, the parameters of the function $\sigma(b)$ (equation 11) in the low precision case were estimated from available data, and the low precision case of σ set equal to the estimated σ_r . For the high precision case, the σ_r and σ_A parameters were set equal to one half the values in the low precision case, and the constant value of σ was set equal to σ_r (Table 2.2 and Figure 2.1). The bias levels were set equal to -1, -2, 1, and 2.

Specifying Lambda (λ_s)

The weighting parameter (λ_s) represents the amount of influence the survey data should have in parameter estimation and was specified as 1300 based on simulations of program CAGEM during its development (Dr. Terrance J. Quinn, II, pers. comm.). To test the performance of λ_s = 1300, a simulation set was run with no specified error in any of the input parameters. The parameter estimates given the R0 reader type and a sample size of 1000 differed from the true parameter estimates by a negligible amount.

A limited sensitivity study to examine the effect of changes in the value of λ_s was also performed where input parameters were specified as in simulation runs 2, 10, and 18 but

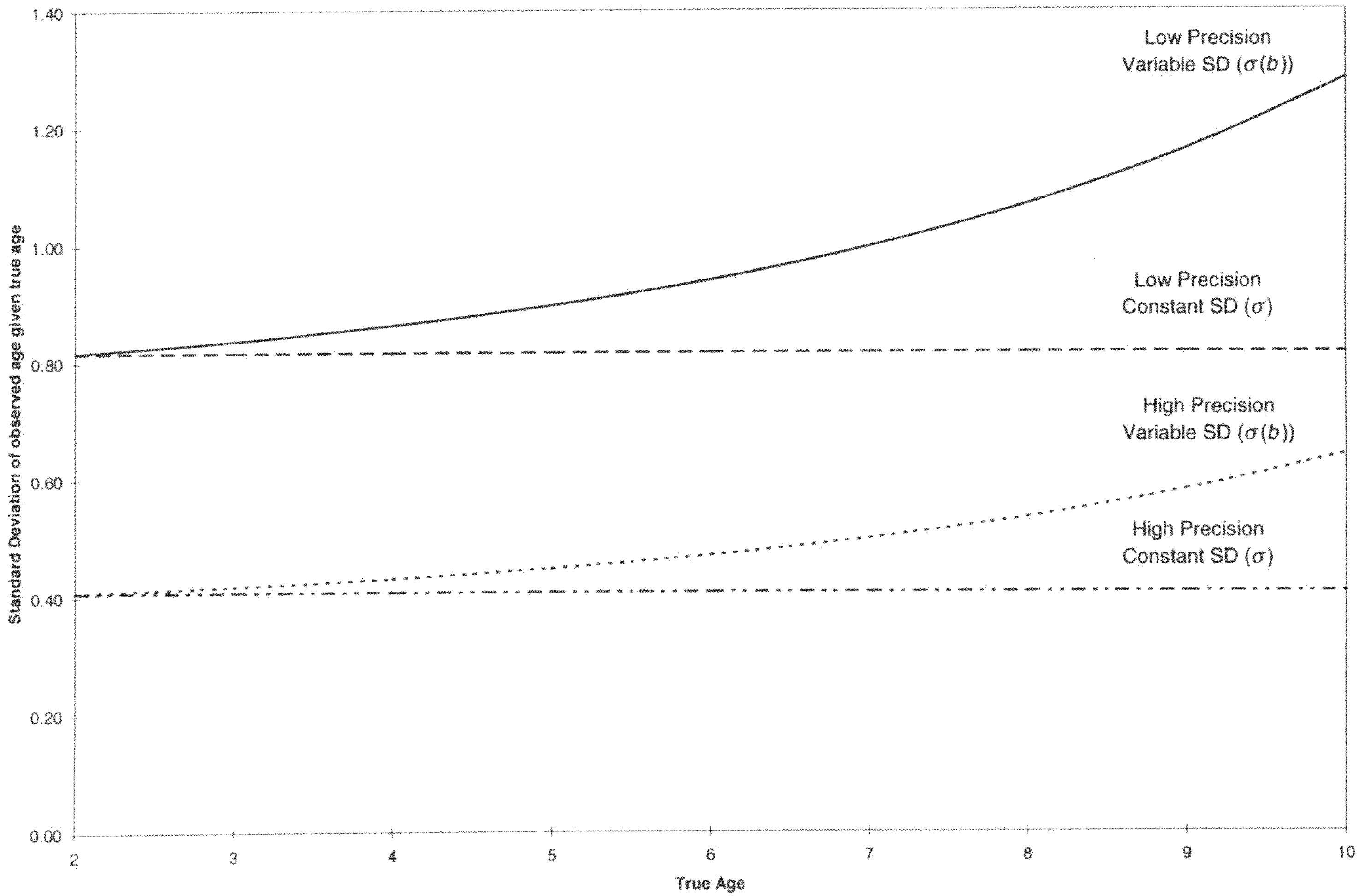


Figure 2.1 Standard deviation of observed age a given true age b for both the high and low precision cases of variable ($\sigma(b)$) and constant (σ) standard deviation.

with λ_s specified as 100 (Table 2.2). These simulations corresponded to low ageing precision, an ageing bias of -2, and sample sizes of 100, 300, and 900.

Data Analysis

To evaluate the process of estimating sustained yield with the QS model and the variable input data detailed above, three statistics were examined. The first was the relative error between the estimated value of a parameter estimate and the true value of that parameter, an indicator of bias. In a Monte Carlo framework, the estimated value of a parameter estimate is equal to the mean of the estimates of that parameter among the Monte Carlo replications. The relative error was then used to perform hypothesis tests to determine if the estimated value of SY_{ST}, SY_{m+}, F_{ST}, F_{m+}, projected abundance, abundance in the first year, abundance in the last year, fishing mortality in the first year, fishing mortality in the last year, and selectivity of age 2 fish differed from the true value by more than an arbitrary 10%. The relative error was calculated as:

$$RE = \frac{\hat{\theta} - \theta}{\theta} \quad , \tag{33}$$

where RE is the relative error, θ is the true value of the parameter, and $\hat{\theta}$ is the estimated value of the parameter estimate. The null and alternative hypotheses were:

H_o: The relative error of the parameter is less than 10%

H_a: The relative error of the parameter is greater than 10%.

Details of the hypothesis testing procedures are given in Appendix D.

The second statistic was the coefficient of variation (CV) of the estimated parameter, an indicator of the precision. In a Monte Carlo framework, the standard deviation among the replicate estimates is a measure of the precision of the parameter estimate given the input data. Therefore, the CV was calculated as the standard deviation of replicate estimates divided by the mean of the replicate estimates.

Following Hightower (1996), the third statistic was the proportion of replicate parameter estimates among Monte Carlo replications that were within 10% of the true value. This statistic, like relative error, is also an indicator of bias but has the additional property of revealing the precision of the process by estimating the probability of obtaining an "accurate" estimate (absolute relative error < 10%).

RESULTS

To simplify labeling in presenting results, a nomenclature system was developed (Table 3.1). This nomenclature is used throughout the following tables and figures to identify reader types and combinations of reader types within scenarios. Appendices E1 to E60 contain summary tables of the estimated value of parameter estimates, coefficient of variation of the parameter estimates, relative error of parameter estimates, and results of testing the hypothesis that parameter estimates are within 10% of the true value. The statistics pertain to SY_{ST} (E1-E6), SY_{m+} (E7-E12), F_{ST} (E13-E18), F_{m+} (E19-E24), projected abundance (E25-E30), abundance in the first year (E31-E36), abundance in the last year (E37-E42), fishing mortality in the first year (E43-E48), fishing mortality in the last year (E49-E54), and selectivity of age 2 fish (E55-E60), respectively. In this section, only those statistics pertinent to sustained yield are investigated, but the others are included for completeness (Appendix E).

3.1 Overview of Sustained Yield Estimation

The estimation of sustained yield relies directly on estimates of sustained fishing mortality, projected abundance, and selectivity of age 2 fish. In general, an increase in any of these parameters will precipitate an increase in sustained yield estimates. To examine relative trends in estimates of these parameters and their affects on the estimation of sustained yield, average relative error in estimates of sustained fishing mortality, projected abundance, selectivity of age 2 fish, and sustained yield were

Table 3.1 Description of nomenclature used for reader type(s)/scenarios.

Variable Name	Scenario	Reader Type(s)	Description
R0	1	R0	One Reader, Single reading
R1	1	R1	One Reader, Single reading
R2	1	R2	One Reader, Single reading
R3	1	R3	One Reader, Single reading
R4	1	R4	One Reader, Single reading
R1M1	2a	R1	One Reader,Three readings, disregard non-modal ages
R2M1	2a	R2	One Reader,Three readings, disregard non-modal ages
R3M1	2a	R3	One Reader,Three readings, disregard non-modal ages
R4M1	2a	R4	One Reader,Three readings, disregard non-modal ages
R1M2	2b	R1	One Reader,Three readings, median of non-modal ages
R2M2	2b	R2	One Reader,Three readings, median of non-modal ages
R3M2	2b	R3	One Reader,Three readings, median of non-modal ages
R4M2	2b	R4	One Reader,Three readings, median of non-modal ages
R1VR1	3	R1, R1	One reading by two readers, rounded mean if disagreement
R2VR2	3	R2, R2	One reading by two readers, expert reader's age if disagreement
R3VR3	3	R3, R3	One reading by two readers, expert reader's age if disagreement
R4VR4	3	R4, R4	One reading by two readers, expert reader's age if disagreement
R2VR3	3	R2, R3	One reading by two readers, expert reader's age if disagreement
R3VR4	3	R3, R4	One reading by two readers, expert reader's age if disagreement
R1F1	4a	R1, R1	Three readings by two readers, disregard non-modal ages
R4F1	4a	R4, R4	Three readings by two readers, disregard non-modal ages
R1F2	4b	R1, R1	Three readings by two readers, median of non-modal ages
R4F2	4b	R4, R4	Three readings by two readers, median of non-modal ages

calculated among all sample sizes, level of ageing imprecision, direction of bias, and among groupings of like reader type(s)/scenarios. These groupings were chosen to best illustrate how bias in estimates of sustained fishing mortality, projected abundance, and selectivity of age 2 fish affect estimates of sustained yield as a function of reader type(s)/scenarios, ageing precision, and ageing bias.

SY_{ST}

Scenarios 1 and 2

The R0 reader type produced highly accurate (relative error < 5%) but slightly negatively biased estimates of SY_{ST}, F_{ST}, and projected abundance, as well as positively biased estimates of the selectivity of age 2 fish (relative error < 10%; Table 3.2; Figures 3.1 - 3.2). Under high ageing precision, the R1 and R2 reader types produced accurate estimates of SY_{ST} (relative error <10%), and moderately accurate estimates of SY_{ST} (relative error ≤ 20%) under low ageing precision. In all cases using the R1 and R2 reader types, the sustained fishing mortality (F_{ST}) and projected abundance was negatively biased while the selectivity of age 2 fish was positively biased. This under-estimation of projected abundance is consistent with the under-estimation of last year abundance and the overestimation of last year fishing mortality for these reader types (Appendices E37-E42, E49-E54).

Under both the high and low cases of ageing precision, positive ageing bias resulted in extreme under-estimation of SY_{ST} (nearly 100% relative error) from both the R3 and R4 reader types. This was primarily a result of extreme under-estimation of F_{ST}, but also a

Table 3.2 Average relative error among estimates of SY_{ST}, F_{ST}, projected abundance, and selectivity of age 2 fish among all sample sizes, groupings of reader type(s)/scenarios, and levels of ageing bias affecting reader types R3 and R4.

Relative error of SY_{ST} among Reader(s)/Scenarios.

Reader(s)/ Scenario	High Precision -Bias	High Precision +Bias	Low Precision -Bias	Low Precision +Bias
R0	-2%	-2%	-2%	-2%
R1, R1M1, R1M2	-3%	-3%	-20%	-20%
R2, R2M1, R2M2	-1%	-1%	-18%	-18%
R3, R3M1, R3M2	39%	-94%	28%	-99%
R4, R4M1, R4M2	38%	-94%	26%	-99%
R1VR1	-20%	-21%	-43%	-43%
R2VR2, R2VR3	1%	-9%	-29%	-41%
R3VR3, R3VR4, R4VR4	-21%	-93%	-71%	-83%
R1F1, R1F2	-5%	-5%	-34%	-34%
R4F1, R4F2	221%	-94%	10%	-77%

Relative error of projected abundance among Reader(s)/Scenarios.

Reader(s)/ Scenario	High Precision -Bias	High Precision +Bias	Low Precision -Bias	Low Precision +Bias
R0	-3%	-3%	-3%	-3%
R1, R1M1, R1M2	-3%	-3%	-11%	-12%
R2, R2M1, R2M2	-2%	-3%	-11%	-11%
R3, R3M1, R3M2	-30%	-61%	-31%	-62%
R4, R4M1, R4M2	-30%	-61%	-32%	-62%
R1VR1	-11%	-11%	-17%	-17%
R2VR2, R2VR3	-2%	-6%	-19%	-20%
R3VR3, R3VR4, R4VR4	-46%	-58%	-59%	-40%
R1F1, R1F2	-4%	-5%	-16%	-16%
R4F1, R4F2	37%	-67%	-13%	-35%

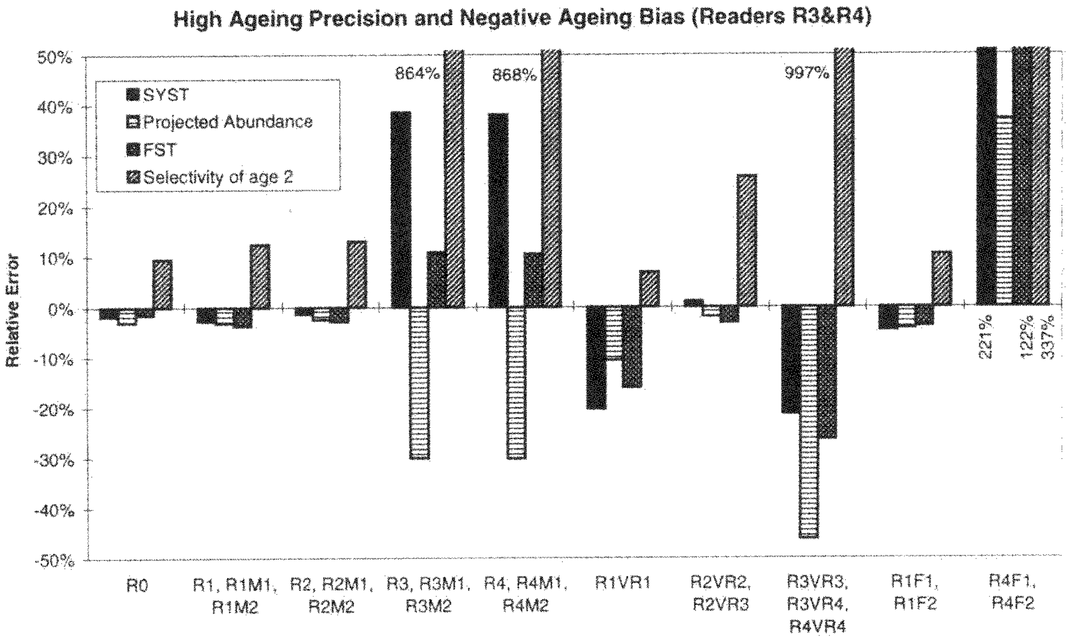
Relative error of F_{ST} among Reader(s)/Scenarios.

Reader(s)/ Scenario	High Precision -Bias	High Precision +Bias	Low Precision -Bias	Low Precision +Bias
R0	-2%	-1%	-2%	-2%
R1, R1M1, R1M2	-4%	-3%	-24%	-24%
R2, R2M1, R2M2	-3%	-3%	-22%	-22%
R3, R3M1, R3M2	11%	-93%	5%	-99%
R4, R4M1, R4M2	11%	-93%	5%	-98%
R1VR1	-16%	-16%	-38%	-38%
R2VR2, R2VR3	-3%	-8%	-32%	-40%
R3VR3, R3VR4, R4VR4	-26%	-91%	-67%	-81%
R1F1, R1F2	-4%	-4%	-28%	-28%
R4F1, R4F2	122%	-92%	-7%	-74%

Relative error of selectivity of age 2 among Reader(s)/Scenarios.

Reader(s)/ Scenario	High Precision -Bias	High Precision +Bias	Low Precision -Bias	Low Precision +Bias
R0	9%	10%	8%	9%
R1, R1M1, R1M2	12%	12%	68%	68%
R2, R2M1, R2M2	13%	13%	72%	72%
R3, R3M1, R3M2	864%	a	820%	a
R4, R4M1, R4M2	868%	a	832%	a
R1VR1	7%	6%	-26%	-25%
R2VR2, R2VR3	26%	10%	122%	38%
R3VR3, R3VR4, R4VR4	997%	a	1000%	a
R1F1, R1F2	10%	10%	-2%	-4%
R4F1, R4F2	337%	a	279%	a

[a] The selectivity of age 2 fish was not estimated among some or all of these simulation runs.



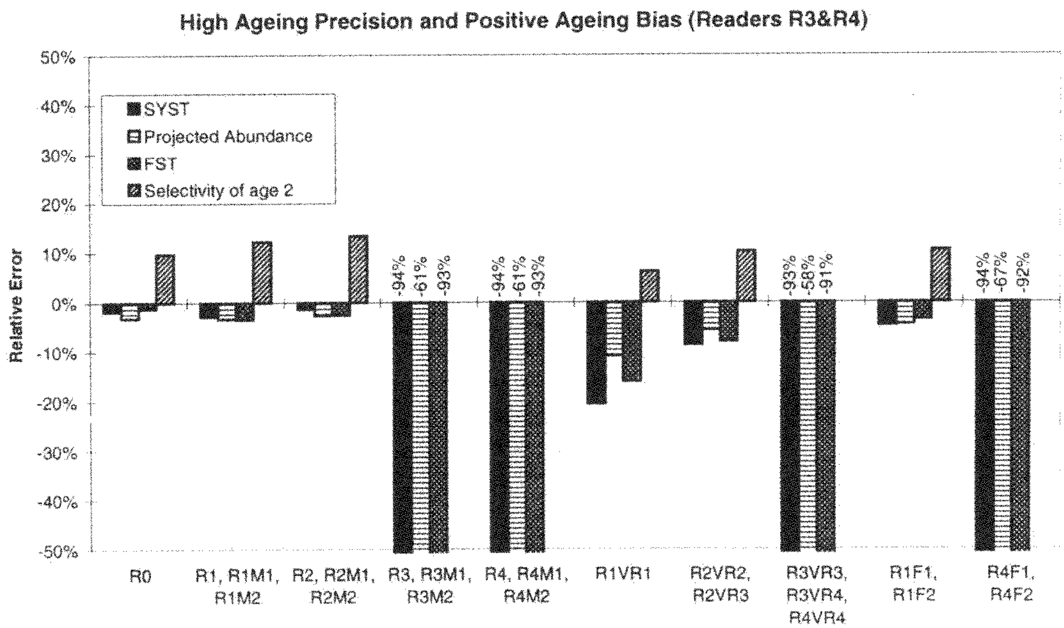
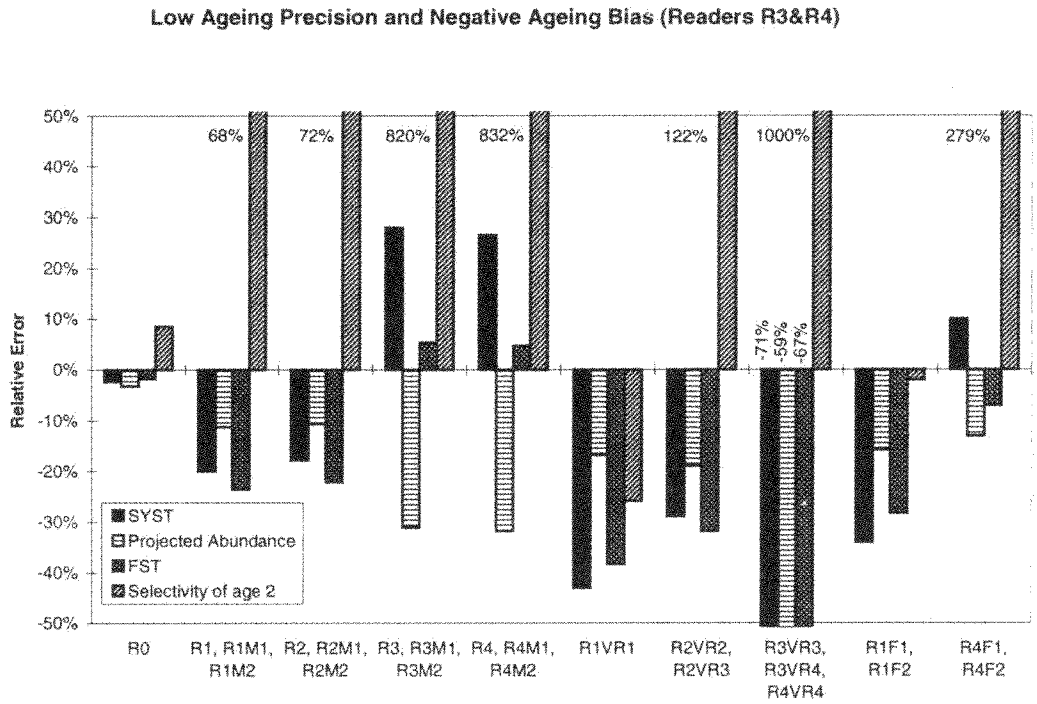


Figure 3.1 Average relative error among estimates of SY_{ST}, F_{ST}, projected abundance, and selectivity of age 2 fish for high ageing precision and positive and negative ageing bias, among all sample sizes and groupings of reader type(s)/scenarios.



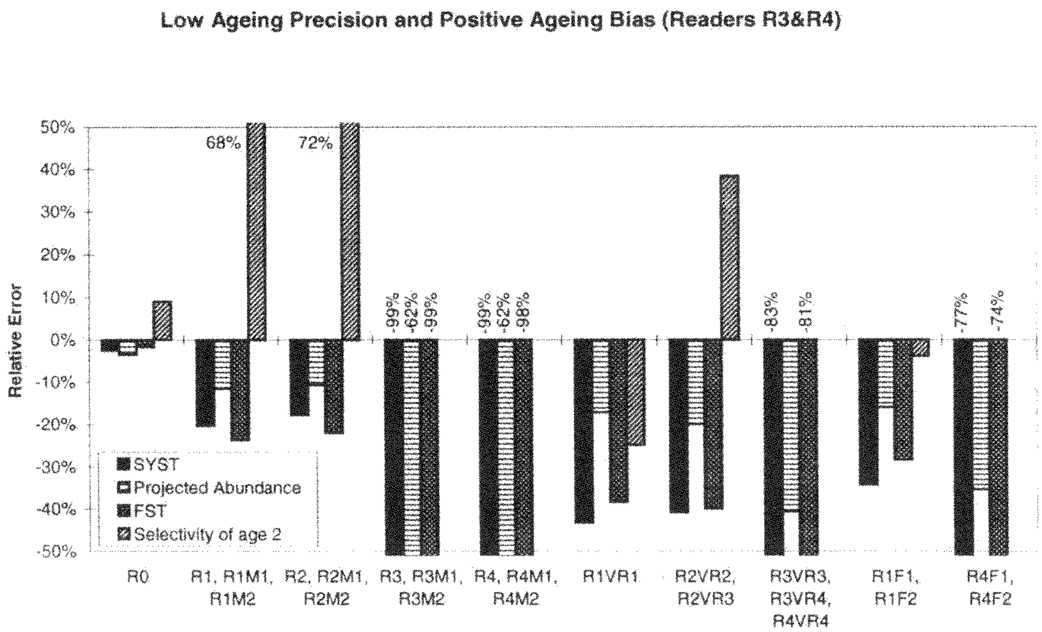


Figure 3.2 Average relative error among estimates of SY_{ST}, F_{ST}, projected abundance, and selectivity of age 2 fish for low ageing precision and positive and negative ageing bias, among all sample sizes and groupings of reader type(s)/scenarios.

result of under-estimation of projected abundance. Additionally, the positive ageing bias resulted in the exclusion of age 2 (+1 bias) and ages 2 and 3 (+2 bias) fish from the analyses and therefore selectivity of age 2 fish was not estimated. Under negative ageing bias, SY_{ST} was over-estimated for both high and low ageing precision using the R3 and R4 reader types. This was a result of moderate over-estimation of F_{ST} (relative error >20%) and huge over-estimation of the selectivity of age 2 fish (relative error > 800%). The high precision case produced more accurate estimates of SY_{ST} than the low precision case given the R3 and R4 reader types under negative ageing bias.

Scenario 3

The R1VR1 reader type combination produced negatively biased estimates of SY_{ST} for both the low and high precision cases with greater under-estimation occurring with the low precision case. Estimates of both projected abundance and F_{ST} were negatively biased under high and low precision cases, while selectivity was biased positively under high precision, and negatively under low precision.

The R2VR2 and R2VR3 (R2VR2,3) combinations of reader types produced quite accurate estimates of SY_{ST} (relative error < 10%) under the high precision case, and marginally accurate estimates under the low precision case (relative error ≤ 41%). In both the high and low precision cases, the R2VR2,3 reader types performed better under negative ageing bias relative to positive ageing bias. Furthermore, the R2VR2,3 reader types produced negatively biased estimates of F_{ST} and projected abundance with greater error under low precision versus high precision. Selectivity of age 2 fish was consistently over-estimated using the R2VR2,3 reader combinations particularly under negative bias and low precision.

The R3VR3, R4VR4, and R3VR4 (R3,4VR3,4) reader type combinations produced highly negatively biased estimates of SY_{ST} (relative error >83%) under positive ageing bias. Additionally, positive ageing bias resulted in the exclusion of age 2 (+1 bias) and ages 2 and 3 (+2 bias) fish from the analysis. The R3,4VR3,4 reader type combinations produced less negatively biased estimates of SY_{ST} under negatively biased ageing error, but produced huge positively biased estimates of selectivity of age 2 fish (relative error approaching 1000%).

Scenario 4

The resultant SY_{ST} estimates from the R1F1 and R1F2 (R1F) reader types were highly accurate (relative error $\leq$ 5%) under high ageing precision with corresponding accurate estimates in F_{ST}, projected abundance, and selectivity of age 2 fish. Under low ageing precision, the R1F combination of reader types produced marginally accurate but negatively biased estimates of SY_{ST} (relative error $\leq$ 35%). Furthermore, under low ageing precision, the R1F readers produced very accurate estimates of the selectivity of age two fish (relative error $\leq$ 4%), and negatively biased estimates of F_{ST} and projected abundance.

Under negative ageing bias, the resultant SY_{ST} estimates from the R4F1 and R4F2 (R4F) reader types had relative error of 221% and 10% for the high and low ageing precision cases, respectively. Under high precision and negative ageing bias, the R4F reader types produced positively biased estimates of SY_{ST}, projected abundance, and selectivity of age 2 fish, and negatively biased estimates of F_{ST}. Under low precision and negative bias, the R4F reader types produced positively biased estimates of SY_{ST} and selectivity of age 2 fish (relative error = 279%), and negatively biased estimates of F_{ST} and projected abundance. Given positive ageing bias and both high and low ageing precision, the R4F reader types produced inaccurate and negatively biased estimates SY_{ST}, F_{ST}, and projected abundance (absolute relative error ≥ 35%). Positive ageing bias again resulted in the exclusion of age 2 (+1 bias) and ages 2 and 3 (+2 bias) fish from the analyses.

SY_{m+}

<u>Scenarios 1 and 2</u>

The trends in the estimation of SY_{m+} for the R0, R1, and R2 reader types are essentially identical to the trends apparent in considering the estimation of SY_{ST}. However, the magnitude of the relative error in SY_{m+} (relative error < 4%) is substantially less than for SY_{ST} (relative error <20%) using low precision and reader types R1 and R2 (Table 3.3; Figures 3.3 - 3.4).

Under negative ageing bias, the relative error in SY_{m+} was negligible for both high and low ageing precision using the R3 and R4 reader types. This result is quite different than the results from the estimation of SY_{ST} and is a result of F_{m+} being under-estimated where in the same circumstance F_{ST} was over-estimated. Under positive ageing bias, SY_{m+} was under-estimated for both high and low ageing precision due to substantial under-

Table 3.3 Average relative error among estimates of SY_{m+}, F_{m+}, projected abundance, and selectivity of age 2 fish among all sample sizes, groupings of reader type(s)/scenarios, and levels of ageing bias affecting reader types R3 and R4.

Relative error of SY_{m+} among Reader(s)/Scenarios.

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	-2%	-2%	-2%	-2%
R1, R1M1, R1M2	-1%	-2%	-4%	-4%
R2, R2M1, R2M2	-1%	-1%	-3%	-3%
R3, R3M1, R3M2	3%	-29%	-1%	-34%
R4, R4M1, R4M2	3%	-30%	-2%	-33%
R1VR1	-9%	-9%	-14%	-14%
R2VR2, R2VR3	1%	-4%	-8%	-12%
R3VR3, R3VR4, R4VR4	-23%	-51%	-44%	-33%
R1F1, R1F2	-3%	-3%	-13%	-13%
R4F1, R4F2	49%	-47%	4%	-33%

Relative error of projected abundance among Reader(s)/Scenarios.

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	-3%	-3%	-3%	-3%
R1, R1M1, R1M2	-3%	-3%	-11%	-12%
R2, R2M1, R2M2	-2%	-3%	-11%	-11%
R3, R3M1, R3M2	-30%	-61%	-31%	-62%
R4, R4M1, R4M2	-30%	-61%	-32%	-62%
R1VR1	-11%	-11%	-17%	-17%
R2VR2, R2VR3	-2%	-6%	-19%	-20%
R3VR3, R3VR4, R4VR4	-46%	-58%	-59%	-40%
R1F1, R1F2	-4%	-5%	-16%	-16%
R4F1, R4F2	37%	-67%	-13%	-35%

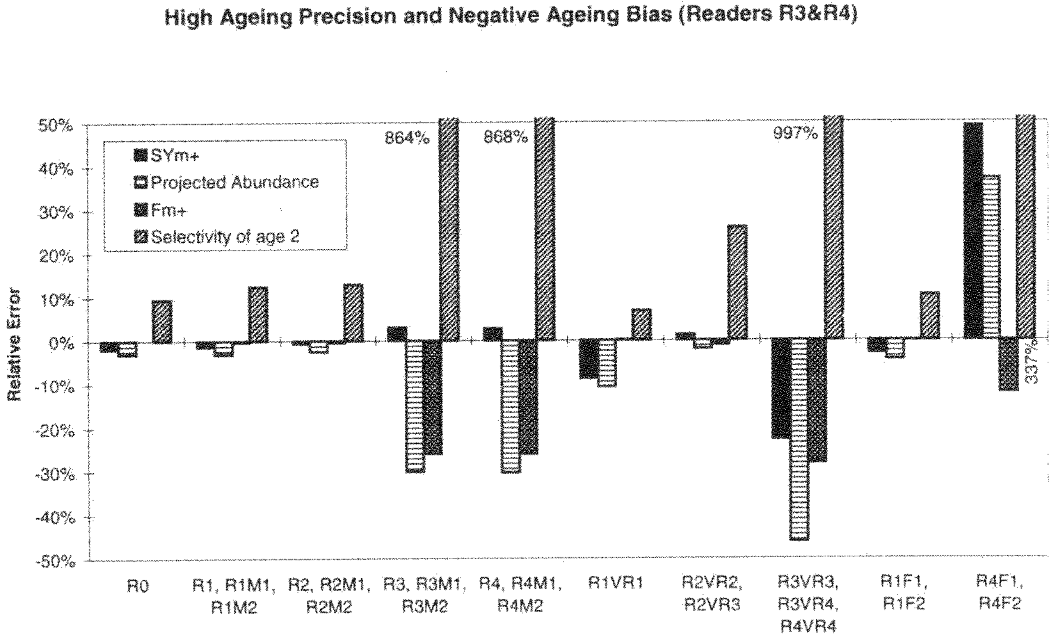
Relative error of F_{m+} among Reader(s)/Scenarios.

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	0%	0%	0%	0%
R1, R1M1, R1M2	0%	0%	-3%	-3%
R2, R2M1, R2M2	0%	0%	-3%	-3%
R3, R3M1, R3M2	-26%	22%	-25%	21%
R4, R4M1, R4M2	-26%	22%	-25%	21%
R1VR1	0%	0%	1%	1%
R2VR2, R2VR3	-1%	0%	-6%	-3%
R3VR3, R3VR4, R4VR4	-28%	3%	-27%	-2%
R1F1, R1F2	0%	0%	1%	1%
R4F1, R4F2	-12%	8%	-11%	0%

Relative error of selectivity of age 2 among Reader(s)/Scenarios.

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	9%	10%	8%	9%
R1, R1M1, R1M2	12%	12%	68%	68%
R2, R2M1, R2M2	13%	13%	72%	72%
R3, R3M1, R3M2	864%	a	820%	a
R4, R4M1, R4M2	868%	a	832%	a
R1VR1	7%	6%	-26%	-25%
R2VR2, R2VR3	26%	10%	122%	38%
R3VR3, R3VR4, R4VR4	997%	a	1000%	a
R1F1, R1F2	10%	10%	-2%	-4%
R4F1, R4F2	337%	a	279%	a

[a] The selectivity of age 2 fish was not estimated among some or all of these simulation runs.



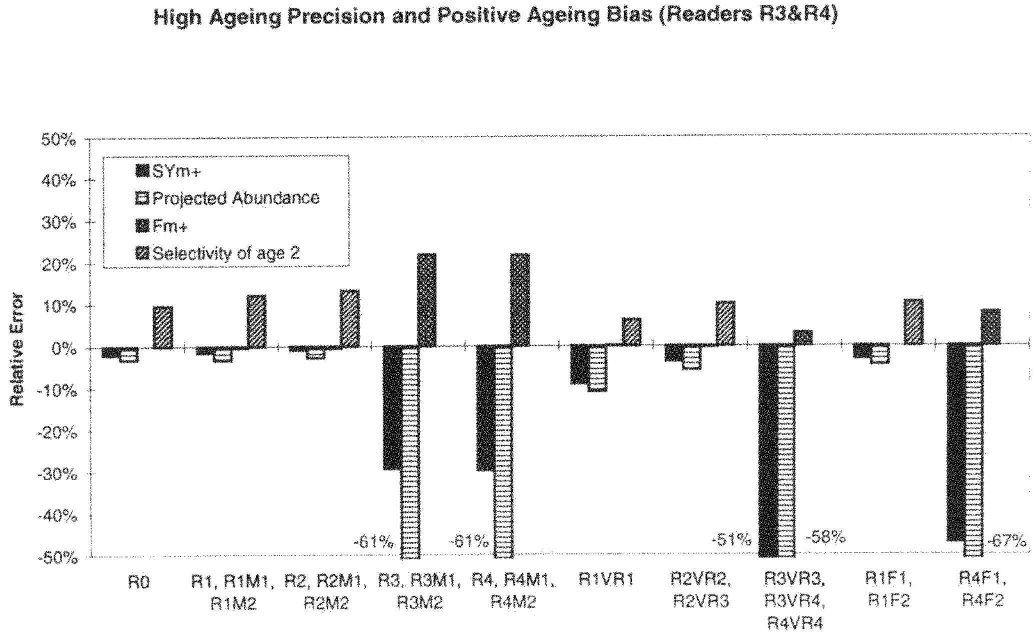
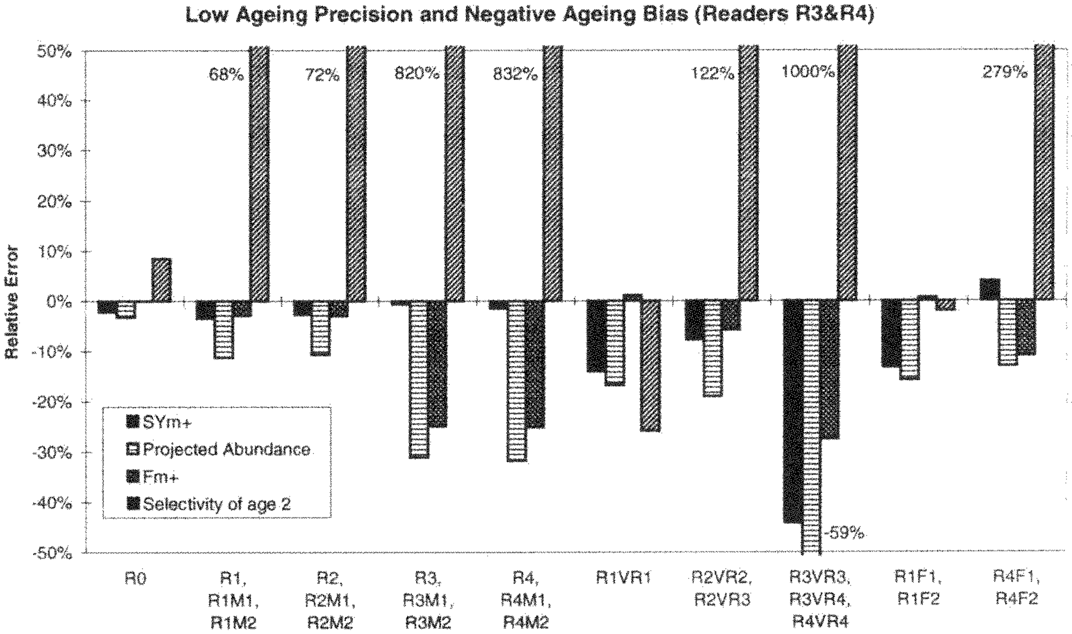


Figure 3.3 Average relative error among estimates of SY_{m+}, F_{m+}, projected abundance, and selectivity of age 2 fish for high ageing precision and positive and negative ageing bias, among all sample sizes and groupings of reader type(s)/scenarios.



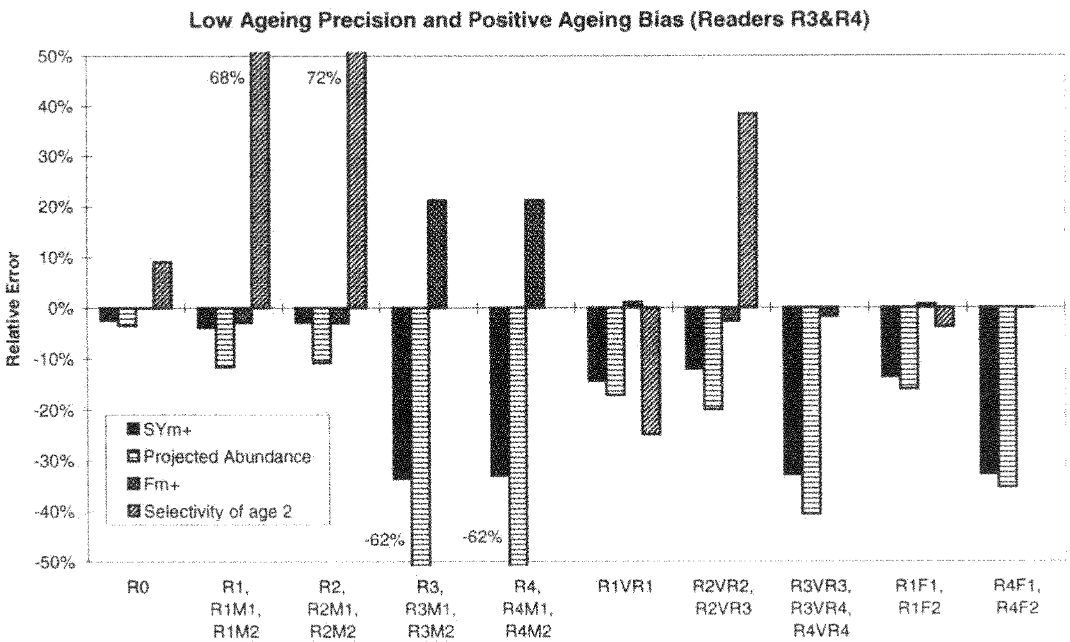


Figure 3.4 Average relative error among estimates of SY_{m+}, F_{m+}, projected abundance, and selectivity of age 2 fish for low ageing precision and positive and negative ageing bias, among all sample sizes and groupings of reader type(s)/scenarios.

estimation of projected abundance (relative error ~ 60%). The error in SY_{m+} under positive ageing bias was mitigated to a degree by the over-estimation of F_{m+}. The estimates of F_{m+} were 0.221 and 0.293 for biases of +1 and +2, respectively, among all simulation runs. This was due to the exclusion of age 2 (bias +1), and ages 2 and 3 (bias +2) from the analyses, and the fact that the estimation of F_{m+} relies only on selectivity and natural mortality. In the case of positive age bias, selectivity was equal to one among all ages considered in the analyses.

Scenario 3

Similar to the estimation of SY_{ST}, the R1VR1 reader type combination produced negatively biased estimates of SY_{m+} for both the low and high precision cases with greater under-estimation occurring under the low precision case. The estimated relative error in F_{m+} was negligible.

The R2VR2,3 combinations of reader types produced accurate estimates of SY_{m+} (relative error $\leq$ 12%) under both the high and low ageing precision cases, with better performance under negative ageing bias relative to positive ageing bias. This result is predominately due to very accurate estimates of F_{m+} (relative error $\leq$ 6%).

The R3,4VR3,4 reader type combinations produced negatively biased estimates of SY_{m+} under both positive and negative ageing bias. The relative error in F_{m+} was negligible under positive ageing bias, and negative under negative ageing bias.

Scenario 4

The trends apparent in the estimation of SY_{m+} from the R1F reader types are similar to those for SY_{ST}. The relative error in the F_{m+} estimates from the R1F reader types was negligible.

Under negative ageing bias, the resultant SY_{m+} estimates from the R4F reader types had relative error of 49% and 4% for the high and low precision cases, respectively. Under negative bias, the R4F reader types produced negatively biased estimates of F_{m+} with relative error $\leq$ 12%. Under positive ageing bias, the R4F reader types produced negatively biased estimates SY_{m+} and projected abundance (relative error $\geq$ 33%) and relatively unbiased estimates of F_{m+} (relative error $\leq$ 8%). Positive ageing bias again resulted in the exclusion of age 2 (+1 bias) and ages 2 and 3 (+2 bias) fish from the analyses.

3.2 Sustained Yield by Reader Type, Ageing Scenario, and Sample Size

In this section, detailed examination of sustained yield by reader type is described.

SY_{ST}

The estimated value of replacement sustained yield (SY_{ST}) in 1992 ranged from a low of 0 fish to a high of 174,925 fish corresponding to relative errors of -100% and 486%, respectively (Appendices E1-E6). Figures 3.5 and 3.6 graphically present the estimated values of SY_{ST} among reader types and scenarios for a sample size of 300. Graphics corresponding to sample sizes of 100 and 900 are not presented because the estimated values of SY_{ST} are very similar among sample sizes (Appendices E1, E3, and E5).

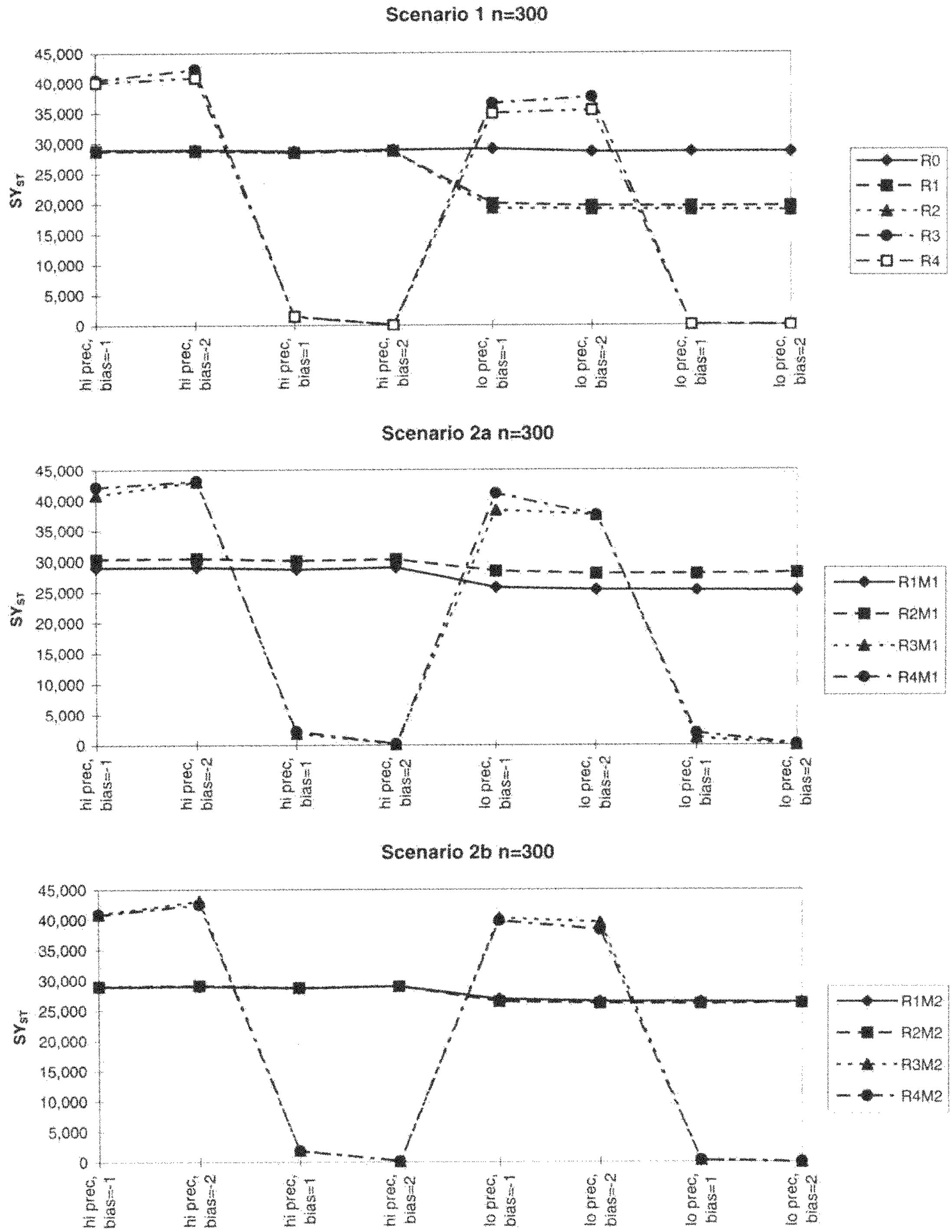
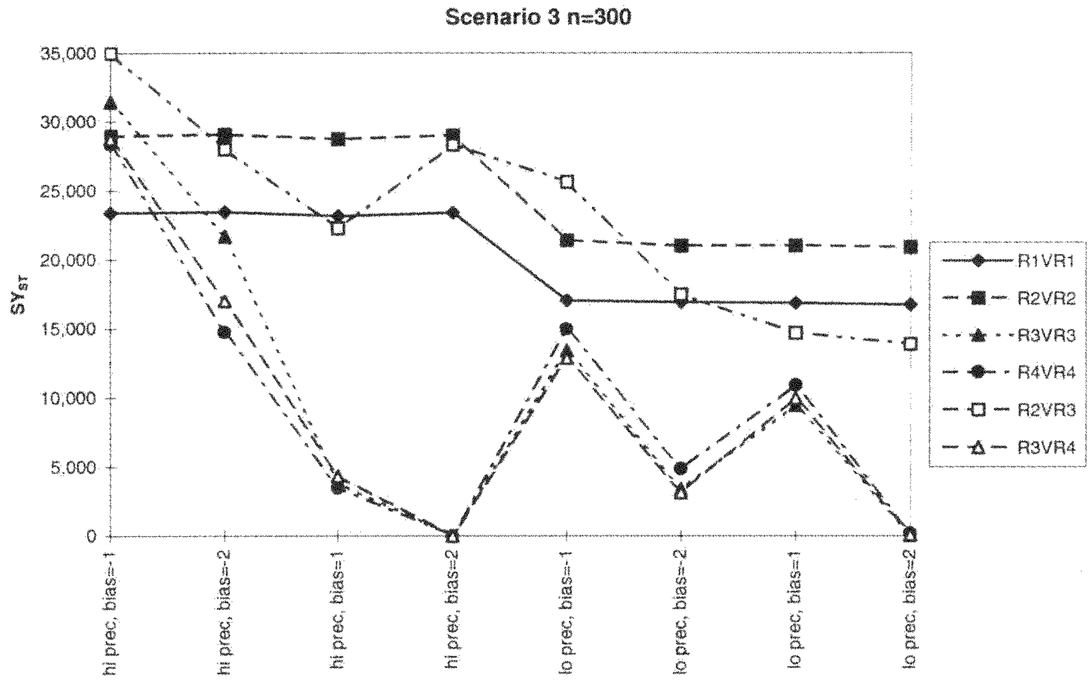


Figure 3.5 Estimated value of SY_{ST} among reader types in scenarios 1, 2a, and 2b (sample size = 300).



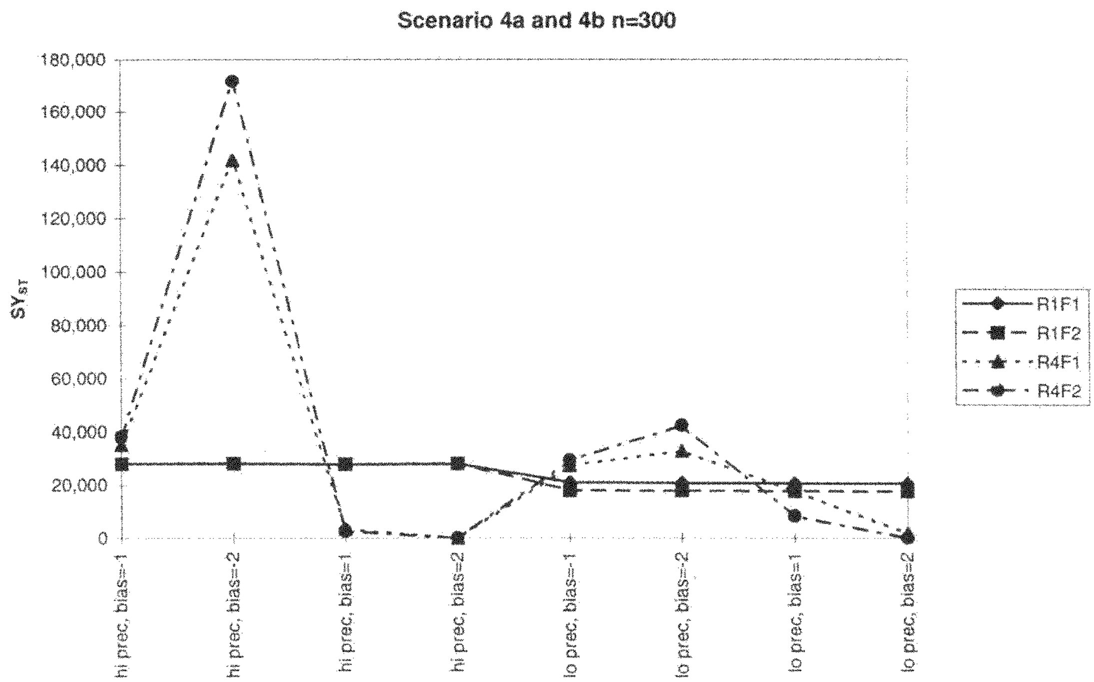


Figure 3.6 Estimated value of SY_{ST} among reader types in scenarios 3, 4a, and 4b (sample size = 300).

Table 3.4 shows the average relative error in SY_{ST} among groupings of reader type(s)/scenarios, and levels of ageing bias. Bold and italicized values are situations where the coefficient of variation of SY_{ST} is greater than 50% (Table 3.5). In each case of high variability there was either an R3 or R4 reader involved and a positive ageing bias. This indicates that positive ageing bias produced consistently imprecise estimates. Furthermore, with regard to all the high variability cases, the apparent trend to either under- or over-estimate SY_{ST} cannot be fully substantiated due to the high variability.

The null hypothesis that the relative difference between the estimated value of SY_{ST} and the true value of SY_{ST} is less than 10% was consistently not rejected among all cases of precision, bias, and sample size, only for the R0 reader in scenario 1 and the R2 reader in scenario 2a (Appendices E2, E4, and E6). The null hypothesis was uniformly rejected among all sample sizes using the R3 and R4 reader types in scenarios 1, 2a, and 2b. In contrast, under high ageing precision, the null hypothesis was not rejected using the R1 and R2 reader types in scenarios 1, 2a, and 2b among all sample sizes. In scenario 3, the null hypothesis was consistently not rejected among all sample sizes only under the following cases: R2VR2 (high precision), R3VR3 (high precision, bias = -1), R4VR4 (high precision, bias = -1), R3VR4 (high precision, bias = -1), and R2VR3 (high precision, bias = -2 and bias = 2). In scenario 4, the null hypothesis was consistently not rejected among all sample sizes only under the following cases: R1F1 (high precision), R1F2 (high precision), and R4F2 (low precision, bias = -1).

Table 3.4 Average relative error of estimates of SY_{ST}, among groupings of reader type(s)/scenarios and levels of ageing bias affecting reader types R3 and R4.

Age Sample Size = 100

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	0%	0%	-1%	-1%
R1, R1M1, R1M2	-3%	-3%	-22%	-22%
R2, R2M1, R2M2	-2%	-2%	-20%	-19%
R3, R3M1, R3M2	34%	*-87%*	24%	*-99%*
R4, R4M1, R4M2	33%	*-89%*	22%	*-98%*
R1VR1	-18%	-19%	-43%	-43%
R2VR2, R2VR3	0%	-9%	-30%	-41%
R3VR3, R3VR4, R4VR4	-24%	*-92%*	-71%	*-83%*
R1F1, R1F2	-3%	-3%	-32%	-32%
R4F1, R4F2	209%	*-92%*	7%	*-77%*

Age Sample Size = 300

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	-3%	-4%	-3%	-4%
R1, R1M1, R1M2	-3%	-4%	-20%	-20%
R2, R2M1, R2M2	-2%	-2%	-17%	-18%
R3, R3M1, R3M2	40%	*-97%*	28%	*-99%*
R4, R4M1, R4M2	39%	*-97%*	27%	*-99%*
R1VR1	-22%	-22%	-43%	-44%
R2VR2, R2VR3	1%	-9%	-28%	-41%
R3VR3, R3VR4, R4VR4	-21%	-94%	-71%	*-83%*
R1F1, R1F2	-6%	-7%	-35%	-36%
R4F1, R4F2	224%	*-95%*	10%	-77%

Age Sample Size = 900

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	-2%	-2%	-2%	-2%
R1, R1M1, R1M2	-2%	-2%	-19%	-19%
R2, R2M1, R2M2	-1%	0%	-16%	-16%
R3, R3M1, R3M2	42%	*-97%*	32%	*-99%*
R4, R4M1, R4M2	41%	*-97%*	30%	*-99%*
R1VR1	-21%	-21%	-43%	-43%
R2VR2, R2VR3	2%	-7%	-28%	-40%
R3VR3, R3VR4, R4VR4	-20%	-94%	-70%	*-83%*
R1F1, R1F2	-5%	-5%	-34%	-34%
R4F1, R4F2	229%	-96%	12%	-77%

Average Over All Sample Sizes

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	-2%	-2%	-2%	-2%
R1, R1M1, R1M2	-3%	-3%	-20%	-20%
R2, R2M1, R2M2	-1%	-1%	-18%	-18%
R3, R3M1, R3M2	39%	*-94%*	28%	*-99%*
R4, R4M1, R4M2	38%	*-94%*	26%	*-99%*
R1VR1	-20%	-21%	-43%	-43%
R2VR2, R2VR3	1%	-9%	-29%	-41%
R3VR3, R3VR4, R4VR4	-21%	*-93%*	-71%	*-83%*
R1F1, R1F2	-5%	-5%	-34%	-34%
R4F1, R4F2	221%	*-94%*	10%	*-77%*

Italicized values reflect combinations of reader type(s)/scenarios and ageing precision and bias that have average CV > 50%.

Table 3.5 Average estimated coefficient of variation of SY_{ST} among groupings of reader type(s)/scenarios and levels of ageing bias affecting reader types R3 and R4.

Age Sample Size = 100

Reader(s)/ Scenario	High Precision -Bias	High Precision +Bias	Low Precision -Bias	Low Precision +Bias
R0	37%	35%	35%	36%
R1, R1M1, R1M2	36%	34%	35%	37%
R2, R2M1, R2M2	35%	34%	36%	37%
R3, R3M1, R3M2	27%	***504%***	28%	***767%***
R4, R4M1, R4M2	27%	***520%***	28%	***729%***
R1VR1	39%	36%	44%	42%
R2VR2, R2VR3	35%	35%	34%	39%
R3VR3, R3VR4, R4VR4	30%	***727%***	40%	***181%***
R1F1, R1F2	38%	36%	42%	42%
R4F1, R4F2	29%	***563%***	*31%*	***711%***

Age Sample Size = 300

Reader(s)/ Scenario	High Precision -Bias	High Precision +Bias	Low Precision -Bias	Low Precision +Bias
R0	25%	26%	25%	24%
R1, R1M1, R1M2	25%	26%	27%	27%
R2, R2M1, R2M2	25%	26%	26%	26%
R3, R3M1, R3M2	23%	***264%***	23%	***682%***
R4, R4M1, R4M2	23%	***252%***	23%	***665%***
R1VR1	25%	27%	30%	30%
R2VR2, R2VR3	25%	26%	26%	28%
R3VR3, R3VR4, R4VR4	23%	76%	31%	***244%***
R1F1, R1F2	25%	26%	29%	29%
R4F1, R4F2	24%	***614%***	24%	50%

Age Sample Size = 900

Reader(s)/ Scenario	High Precision -Bias	High Precision +Bias	Low Precision -Bias	Low Precision +Bias
R0	22%	22%	23%	22%
R1, R1M1, R1M2	22%	22%	24%	23%
R2, R2M1, R2M2	22%	22%	24%	23%
R3, R3M1, R3M2	21%	***327%***	22%	***488%***
R4, R4M1, R4M2	21%	***317%***	22%	***323%***
R1VR1	23%	23%	26%	25%
R2VR2, R2VR3	22%	23%	24%	24%
R3VR3, R3VR4, R4VR4	22%	56%	28%	***331%***
R1F1, R1F2	22%	22%	25%	24%
R4F1, R4F2	22%	61%	22%	42%

Average Over All Sample Sizes

Reader(s)/ Scenario	High Precision -Bias	High Precision +Bias	Low Precision -Bias	Low Precision +Bias
R0	28%	28%	28%	27%
R1, R1M1, R1M2	28%	28%	29%	29%
R2, R2M1, R2M2	28%	28%	29%	29%
R3, R3M1, R3M2	24%	***365%***	24%	***646%***
R4, R4M1, R4M2	24%	***363%***	24%	***573%***
R1VR1	29%	29%	33%	32%
R2VR2, R2VR3	27%	28%	28%	31%
R3VR3, R3VR4, R4VR4	25%	***286%***	33%	***252%***
R1F1, R1F2	28%	28%	32%	32%
R4F1, R4F2	25%	***413%***	26%	***268%***

These results support the general trend that ageing bias and low ageing precision leads to biased estimates of SY_{ST}.

While sample size did not substantially affect the average relative error, it was important in the variability of the sustained yield estimates. This is shown by both the CV of the sustained yield estimates and the proportion of replicated estimates which produced accurate (relative error <10%) estimates of sustained yield. Recall that the proportion of accurate replicate estimates is an indication of the probability of producing an accurate estimate and is therefore a combined measure of bias and precision.

It is apparent that the CV of the sustained yield estimates decreased as a function of sample size for each reader type (Table 3.5). Additionally, there were larger decreases in CV between the sample sizes of 100 and 300 than among 300 and 900. The proportion of replicate estimates of SY_{ST} that were within 10% of the true ranged between 0% and 40% among all levels of specified ageing error, scenarios, and sample sizes (Figures 3.7 - 3.11). As expected, the highest proportions were obtained when employing reader R0, with proportions ranging from approximately 25%, 33%, and 35% among sample sizes of 100, 300, and 900, respectively (Figure 3.7). For readers R1 and R2, the proportions were essentially identical to the R0 reader type in scenario 1 under high ageing precision, but dropped substantially under low ageing precision (Figure 3.7). However this same pattern is not nearly as evident for the R1 and R2 readers in scenarios 2a and 2b where multiple readings were made by each reader type (Figures 3.8 and 3.9). For readers R3

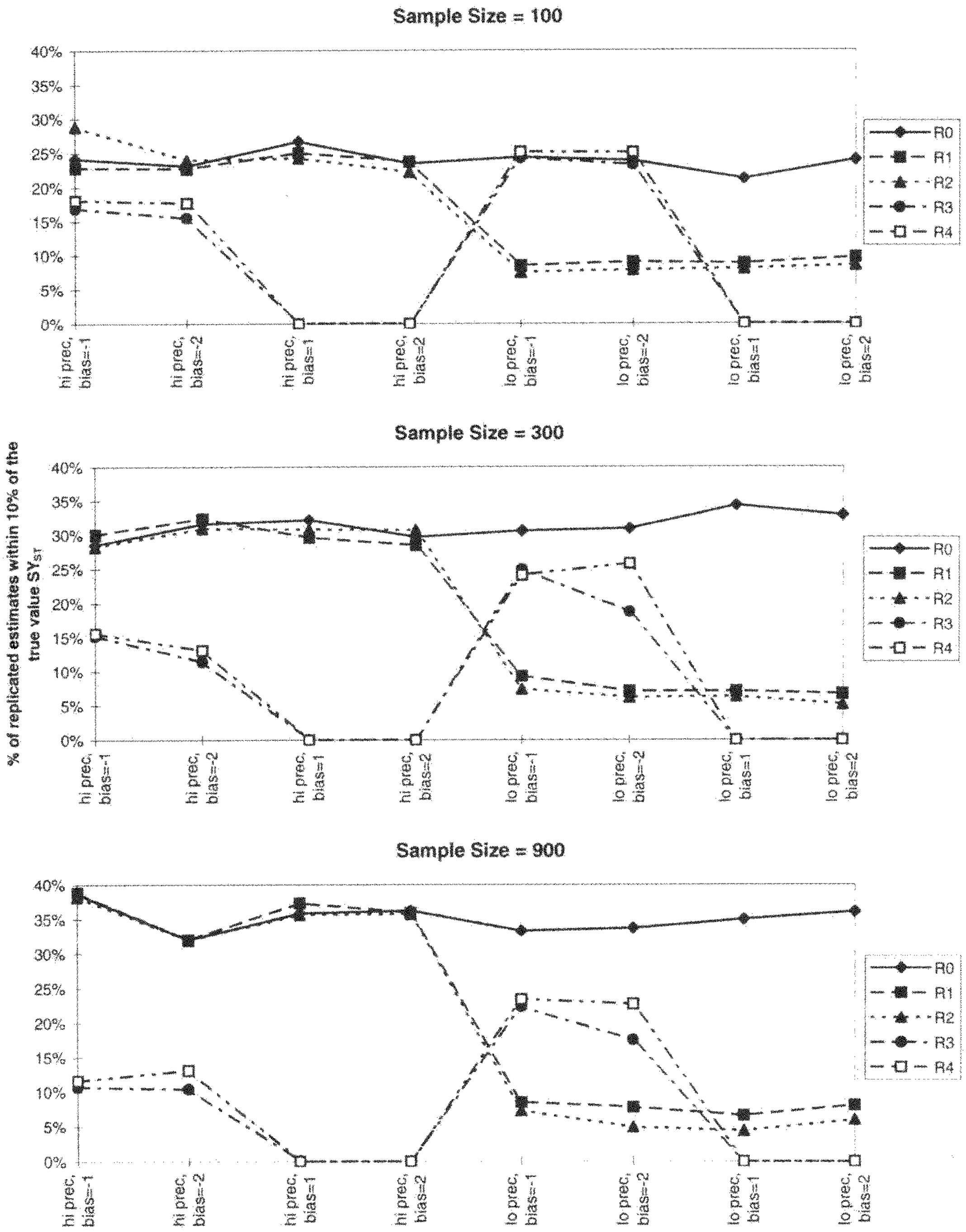


Figure 3.7 Proportion of Monte Carlo replicates that produced estimates of SY_{ST} that were within 10% of the true value in scenario 1 with sample sizes 100, 300, and 900.

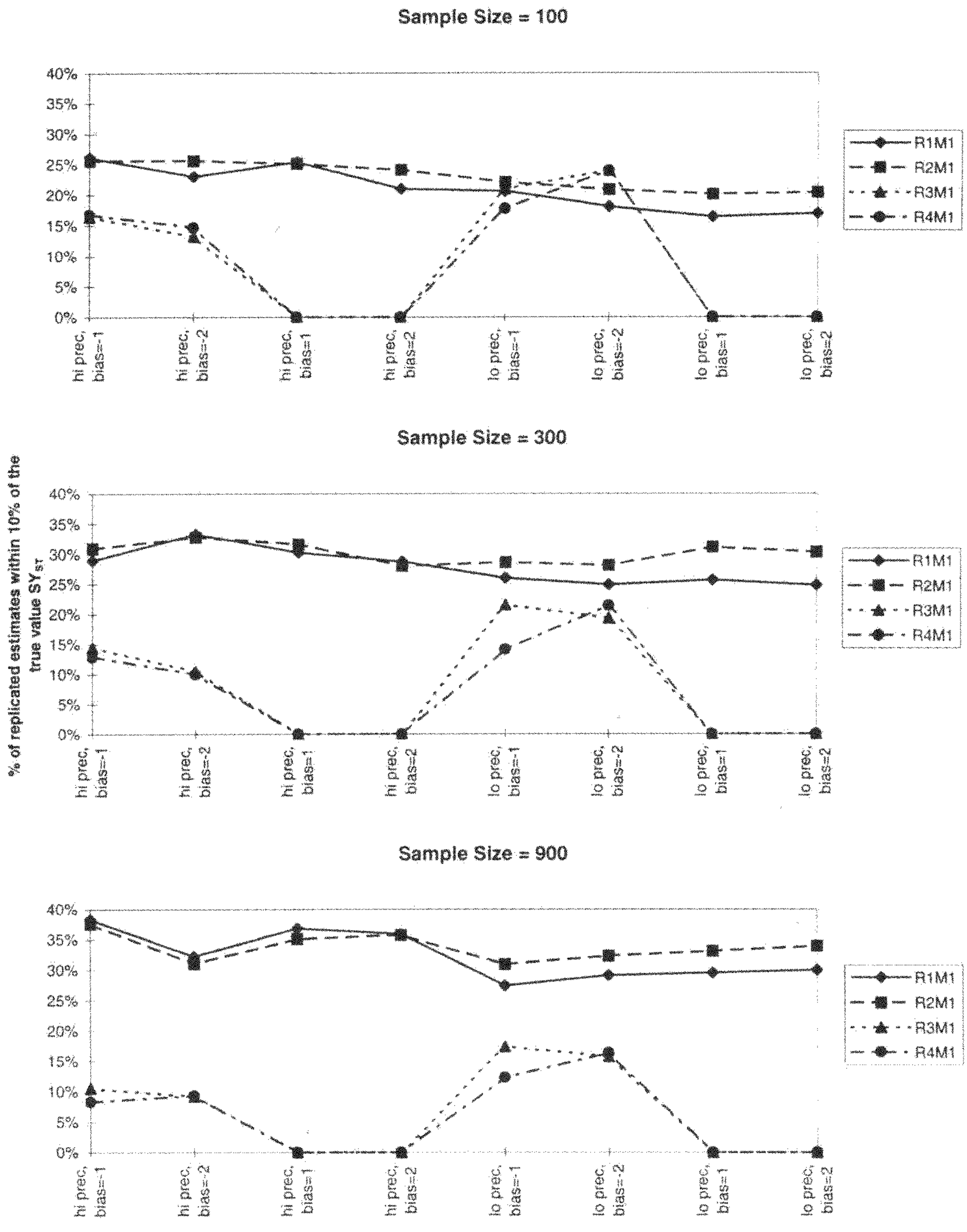


Figure 3.8 Proportion of Monte Carlo replicates that produced estimates of SY_{ST} that were within 10% of the true value in scenario 2a with sample sizes 100, 300, and 900.

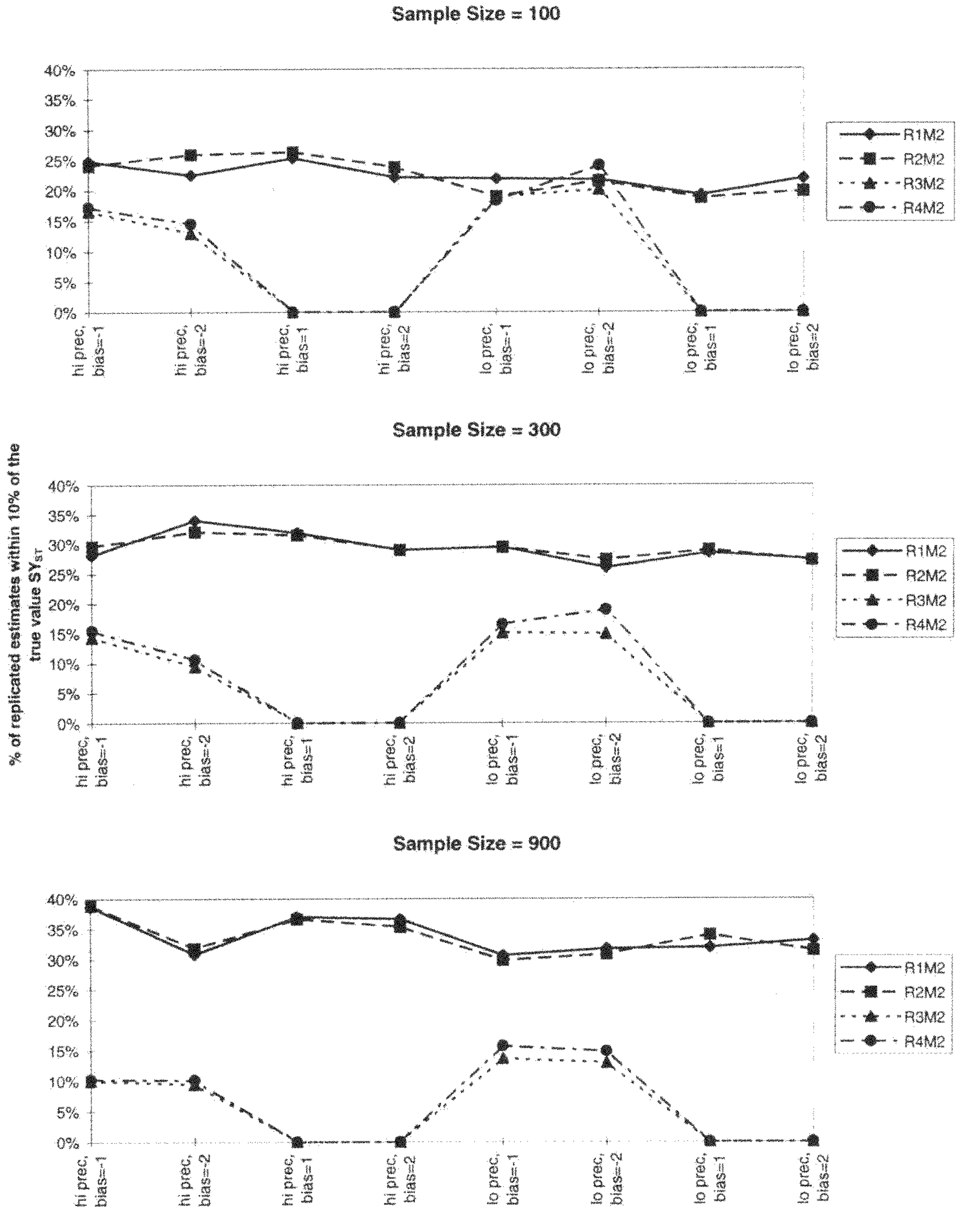


Figure 3.9 Proportion of Monte Carlo replicates that produced estimates of SY_{ST} that were within 10% of the true value in scenario 2b with sample sizes 100, 300, and 900.

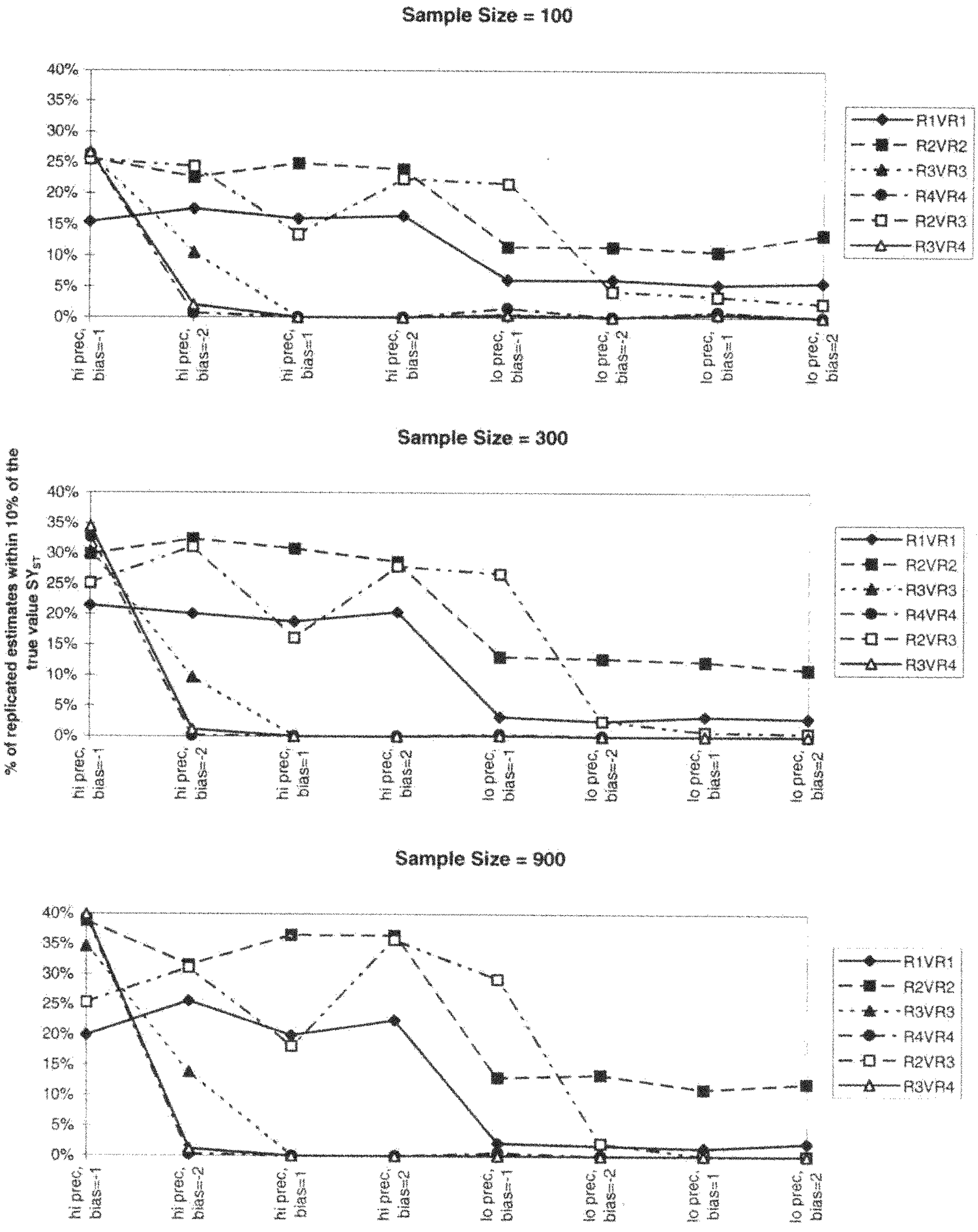


Figure 3.10 Proportion of Monte Carlo replicates that produced estimates of SY_{ST} that were within 10% of the true value in scenario 3 with sample sizes 100, 300, and 900.

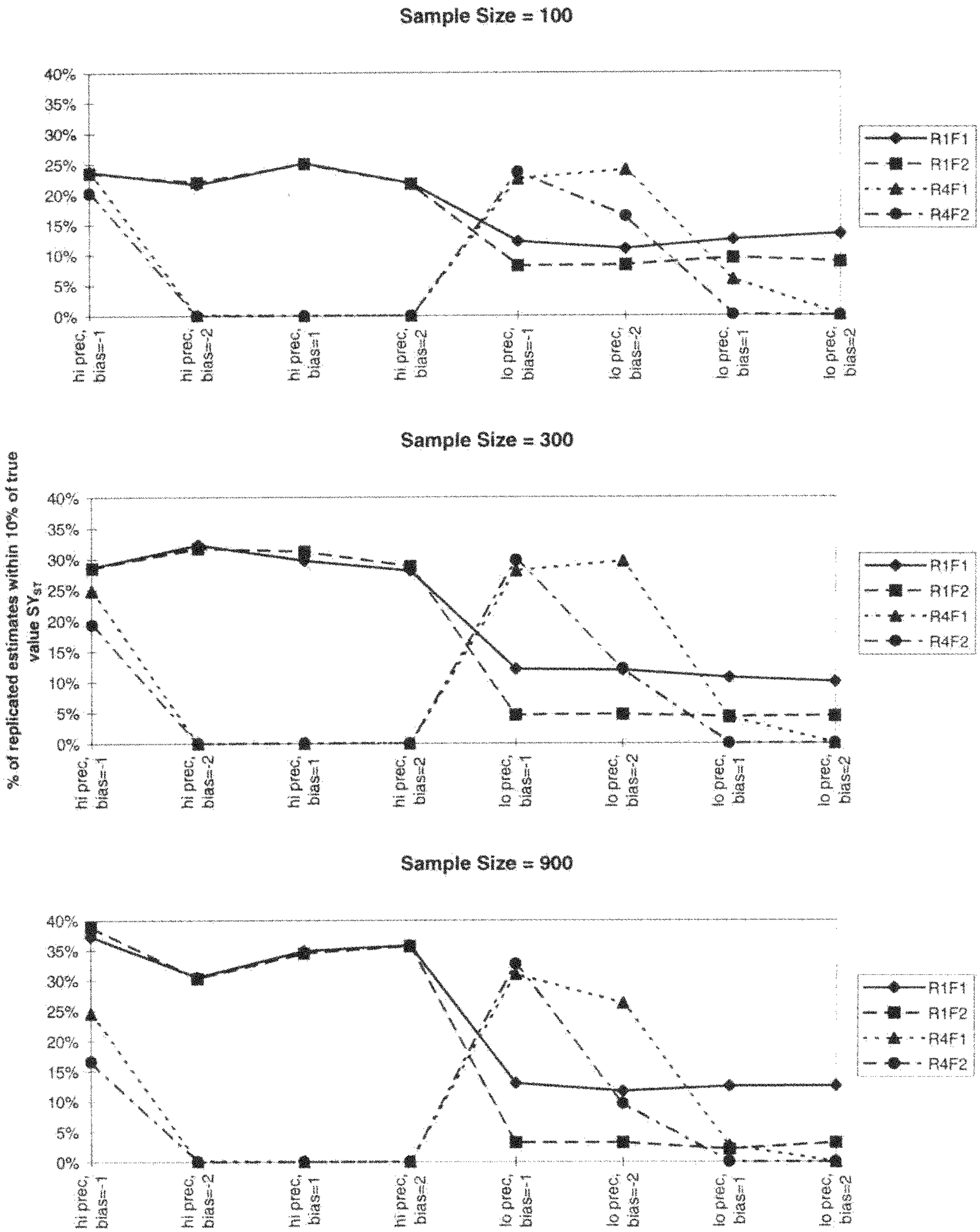


Figure 3.11 Proportion of Monte Carlo replicates that produced estimates of SY_{ST} that were within 10% of the true value in scenarios 4a and 4b with sample sizes 100, 300, and 900.

and R4, the proportions of accurate estimates ranged from 0% to approximately 25% among scenarios 1, 2a, and 2b and sample sizes of 100, 300, and 900. Under positive ageing bias, the proportions were uniformly zero in scenarios 1, 2a, and 2b among all sample sizes and levels of precision. In scenario 3 with two readers, the proportions of accurate estimates ranged from 0% to 25%, 0% to 35%, and 0% to 40% for sample sizes of 100, 300, and 900, respectively (Figure 3.10). Among all sample sizes in scenario 3, the high precision case produced proportions ranging from 0% to 40% while the low precision case produced proportions ranging from 0% to approximately 30%. The R2VR2 and R2VR3 combinations of reader types consistently had the highest proportions of accurate estimates. The R1VR1 performed relatively poorly compared to the R2VR2 and R2VR3 combinations, suggesting that resolving disputes in the age of individual structures among two expert by using a rounded mean doesn't result in accurate estimates of SY_{ST}. The R3VR3, R4VR4, and R3VR4 combinations produced the lowest proportions of accurate estimates except in the situation of high precision and a bias of -1.

In scenario 4 where multiple readers make multiple readings, the proportions of accurate estimates ranged between 0% and 40% among all sample sizes and reader types (Figure 3.11). The R1F combinations of readers produced a similar pattern among high and low precision cases to those seen in scenario 1, with large differences in proportions between the low and high precision cases. The R4F combinations of readers also produced similar patterns compared to the R4 reader type in scenario 1 with the major differences being that R4F had a zero proportion of accurate estimates under high precision and bias = -2.

The general trend supported by these results is that increasing sample size results in decreasing the CV of sustained yield estimates but can either increase or decrease the probability of obtaining and accurate estimate. For the reader types producing unbiased estimates of sustained yield, the decrease in CV of sustained yield estimates is accompanied by an increase in the probability of obtaining an accurate estimate. For the reader types producing biased sustained yield estimates, the decrease in the CV of sustained yield estimates is accompanied by a decrease in the probability of obtaining an accurate estimate as the "tail" of the distribution recedes away from the true value. The results further show that the probability of obtaining an accurate estimate increases only if the catch-age composition is being estimated by a precise and unbiased reader type(s).

SY_{m+}

The estimated value of sustained yield to maximize the catch of fully mature fish (SY_{m+}) in 1992 ranged from a low of 5,256 fish to a high of 34,904 fish corresponding to relative errors of -69% and 105%, respectively (Appendices E7-E12). Figures 3.12 and 3.13 present the estimated values of SY_{m+} among reader types and scenarios for a sample size of 300. Graphics corresponding to sample sizes of 100 and 900 are not presented because the estimated expected values of SY_{m+} are very similar among sample sizes (Appendices E7, E9, and E11). Table 3.6 shows the average relative error in SY_{ST} among groupings of reader type(s)/scenarios and levels of ageing bias. The coefficient of variation of SY_{m+} among groupings of reader type(s)/scenarios and levels of ageing bias was consistently less than for SY_{ST} (Table 3.7).

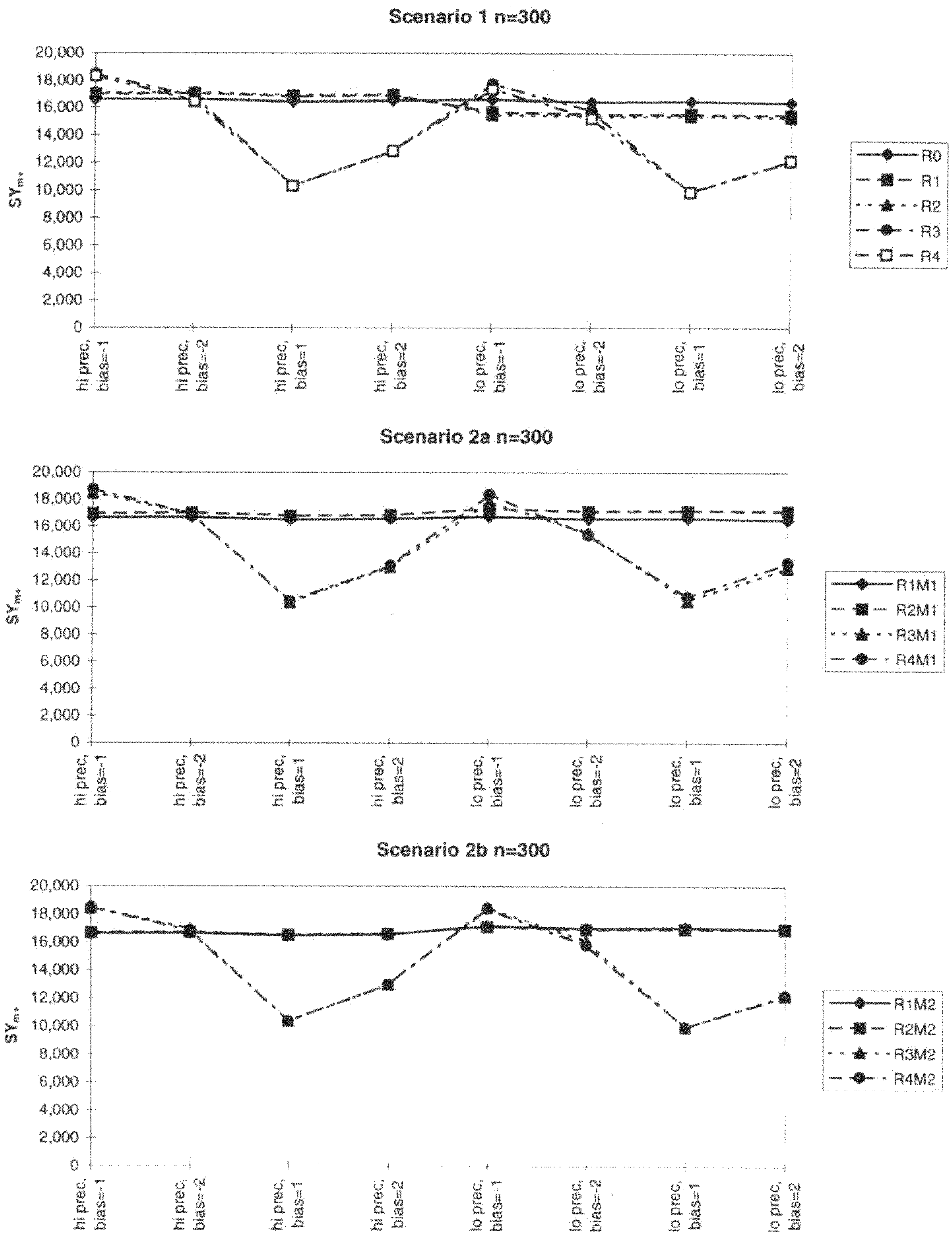
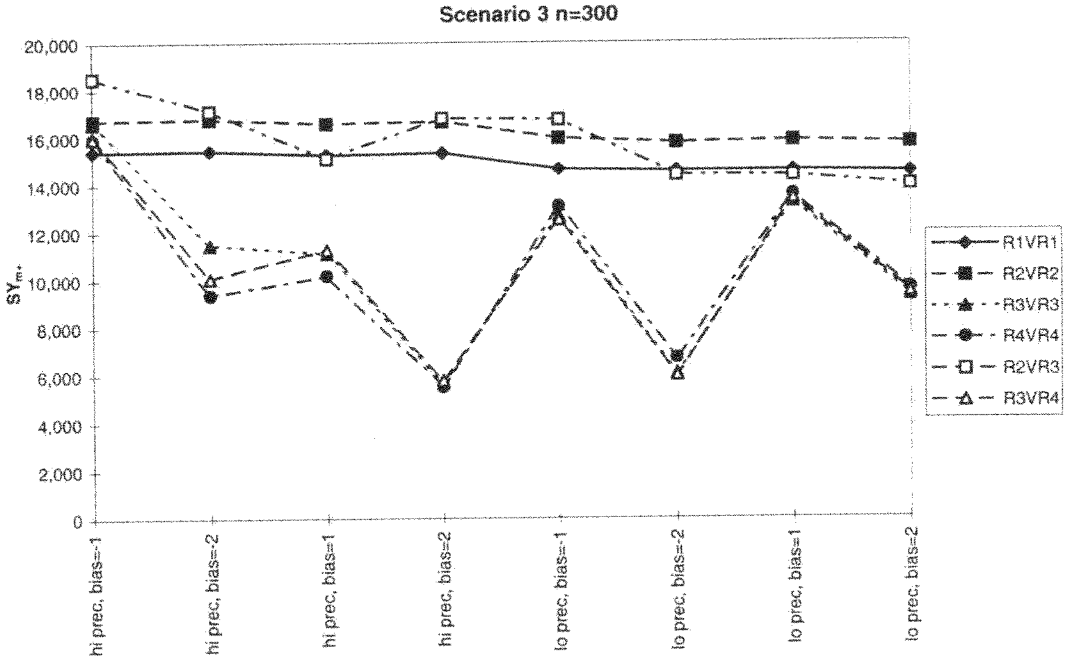


Figure 3.12 Estimated value of SY_{m+} among reader types in scenarios 1, 2a, and 2b (sample size = 300).



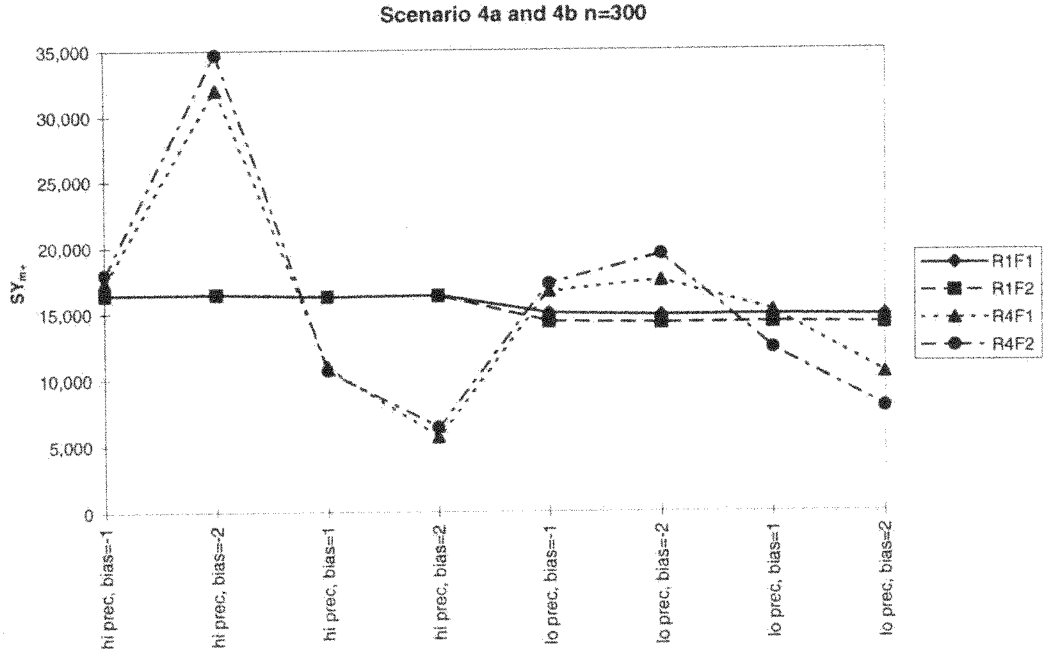


Figure 3.13 Estimated value of SY_{m+} among reader types in scenarios 3, 4a, and 4b (sample size = 300).

Table 3.6 Average relative error of estimates of SY_{m+} among groupings of reader type(s)/scenarios and levels of ageing bias affecting reader types R3 and R4.

Age Sample Size = 100

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	-1%	-1%	-1%	-1%
R1, R1M1, R1M2	-1%	-1%	-4%	-5%
R2, R2M1, R2M2	-1%	-1%	-4%	-4%
R3, R3M1, R3M2	1%	-26%	-2%	-34%
R4, R4M1, R4M2	1%	-27%	-3%	-33%
R1VR1	-7%	-8%	-14%	-14%
R2VR2, R2VR3	1%	-4%	-8%	-12%
R3VR3, R3VR4, R4VR4	-24%	-49%	-44%	-33%
R1F1, R1F2	-2%	-2%	-12%	-12%
R4F1, R4F2	46%	-37%	3%	-33%

Age Sample Size = 300

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	-3%	-3%	-3%	-4%
R1, R1M1, R1M2	-1%	-2%	-3%	-4%
R2, R2M1, R2M2	-1%	-1%	-3%	-3%
R3, R3M1, R3M2	4%	-32%	-1%	-34%
R4, R4M1, R4M2	3%	-31%	-2%	-33%
R1VR1	-9%	-10%	-14%	-15%
R2VR2, R2VR3	2%	-4%	-8%	-12%
R3VR3, R3VR4, R4VR4	-22%	-52%	-44%	-33%
R1F1, R1F2	-4%	-4%	-14%	-15%
R4F1, R4F2	50%	-51%	4%	-33%

Age Sample Size = 900

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	-2%	-2%	-2%	-3%
R1, R1M1, R1M2	-1%	-1%	-3%	-3%
R2, R2M1, R2M2	-1%	0%	-2%	-2%
R3, R3M1, R3M2	5%	-31%	1%	-33%
R4, R4M1, R4M2	4%	-31%	0%	-33%
R1VR1	-9%	-9%	-14%	-14%
R2VR2, R2VR3	2%	-3%	-7%	-11%
R3VR3, R3VR4, R4VR4	-22%	-52%	-44%	-32%
R1F1, R1F2	-3%	-3%	-14%	-14%
R4F1, R4F2	51%	-54%	5%	-32%

Average over all sample Sizes

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	-2%	-2%	-2%	-2%
R1, R1M1, R1M2	-1%	-2%	-4%	-4%
R2, R2M1, R2M2	-1%	-1%	-3%	-3%
R3, R3M1, R3M2	3%	-29%	-1%	-34%
R4, R4M1, R4M2	3%	-30%	-2%	-33%
R1VR1	-9%	-9%	-14%	-14%
R2VR2, R2VR3	1%	-4%	-8%	-12%
R3VR3, R3VR4, R4VR4	-23%	-51%	-44%	-33%
R1F1, R1F2	-3%	-3%	-13%	-13%
R4F1, R4F2	49%	-47%	4%	-33%

Table 3.7 Average estimated coefficient of variation of SY_{m+} among groupings of reader type(s)/scenarios and levels of ageing bias affecting reader types R3 and R4.

Age Sample Size = 100

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	21%	21%	20%	21%
R1, R1M1, R1M2	20%	20%	19%	20%
R2, R2M1, R2M2	20%	20%	19%	20%
R3, R3M1, R3M2	19%	44%	19%	15%
R4, R4M1, R4M2	19%	39%	19%	15%
R1VR1	21%	20%	22%	21%
R2VR2, R2VR3	20%	20%	18%	20%
R3VR3, R3VR4, R4VR4	19%	22%	18%	20%
R1F1, R1F2	22%	21%	22%	22%
R4F1, R4F2	19%	39%	18%	21%

Age Sample Size = 300

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	16%	16%	16%	15%
R1, R1M1, R1M2	16%	16%	16%	16%
R2, R2M1, R2M2	16%	16%	16%	16%
R3, R3M1, R3M2	17%	15%	17%	14%
R4, R4M1, R4M2	17%	15%	17%	14%
R1VR1	16%	16%	16%	17%
R2VR2, R2VR3	16%	16%	16%	16%
R3VR3, R3VR4, R4VR4	17%	19%	16%	16%
R1F1, R1F2	16%	16%	17%	16%
R4F1, R4F2	17%	24%	16%	16%

Age Sample Size = 900

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	15%	15%	16%	15%
R1, R1M1, R1M2	15%	15%	16%	15%
R2, R2M1, R2M2	15%	15%	16%	15%
R3, R3M1, R3M2	17%	14%	17%	14%
R4, R4M1, R4M2	17%	14%	17%	14%
R1VR1	15%	15%	16%	15%
R2VR2, R2VR3	15%	15%	16%	15%
R3VR3, R3VR4, R4VR4	16%	16%	16%	15%
R1F1, R1F2	15%	15%	16%	15%
R4F1, R4F2	16%	16%	16%	15%

Average Over All Sample Sizes

Reader(s)/ Scenario	High Precision		Low Precision	
	-Bias	+Bias	-Bias	+Bias
R0	17%	17%	17%	17%
R1, R1M1, R1M2	17%	17%	17%	17%
R2, R2M1, R2M2	17%	17%	17%	17%
R3, R3M1, R3M2	18%	24%	18%	14%
R4, R4M1, R4M2	18%	22%	18%	14%
R1VR1	17%	17%	18%	18%
R2VR2, R2VR3	17%	17%	17%	17%
R3VR3, R3VR4, R4VR4	17%	19%	16%	17%
R1F1, R1F2	17%	17%	18%	18%
R4F1, R4F2	17%	26%	17%	17%

Among scenarios 1, 2a, and 2b and all samples sizes, the only circumstances where the null hypothesis that the relative difference between the estimated value of SY_{m+} and the true value of SY_{m+} is less than 10% was rejected were among reader types R3 and R4 under positive ageing bias (Appendices E8, E10, and E12). Additionally, among all reader types, scenarios, and sample sizes, the null hypothesis was not rejected under high precision and bias = -1. In scenario 3, the null hypothesis was uniformly not rejected for the R2VR2 combination among all sample sizes and levels of precision, and for the R1VR1 combination under high precision. The null hypothesis was rejected under all cases except high precision and bias = -1 for the R3VR3, R4VR4, and R3VR4 combinations. Finally, the null hypothesis was rejected among all cases in scenario 4 with the exception of R1F under high precision, R4F under a bias of -1, and R4F1 under low precision and negative bias. These results support the general trend that ageing bias leads to biased estimates of SY_{m+}.

Similar to SY_{ST}, the CV of SY_{m+} decreased consistently as a function of sample size with the largest decreases occurring between sample sizes of 100 to 300 (Table 3.7). The proportion of replicate estimates of SY_{m+} within 10% of the true value ranged between 0% and 56% among all levels of specified ageing error, scenarios, and sample sizes (Figures 3.14 - 3.18). In scenarios 1, 2a, and 2b, proportions were very similar among the

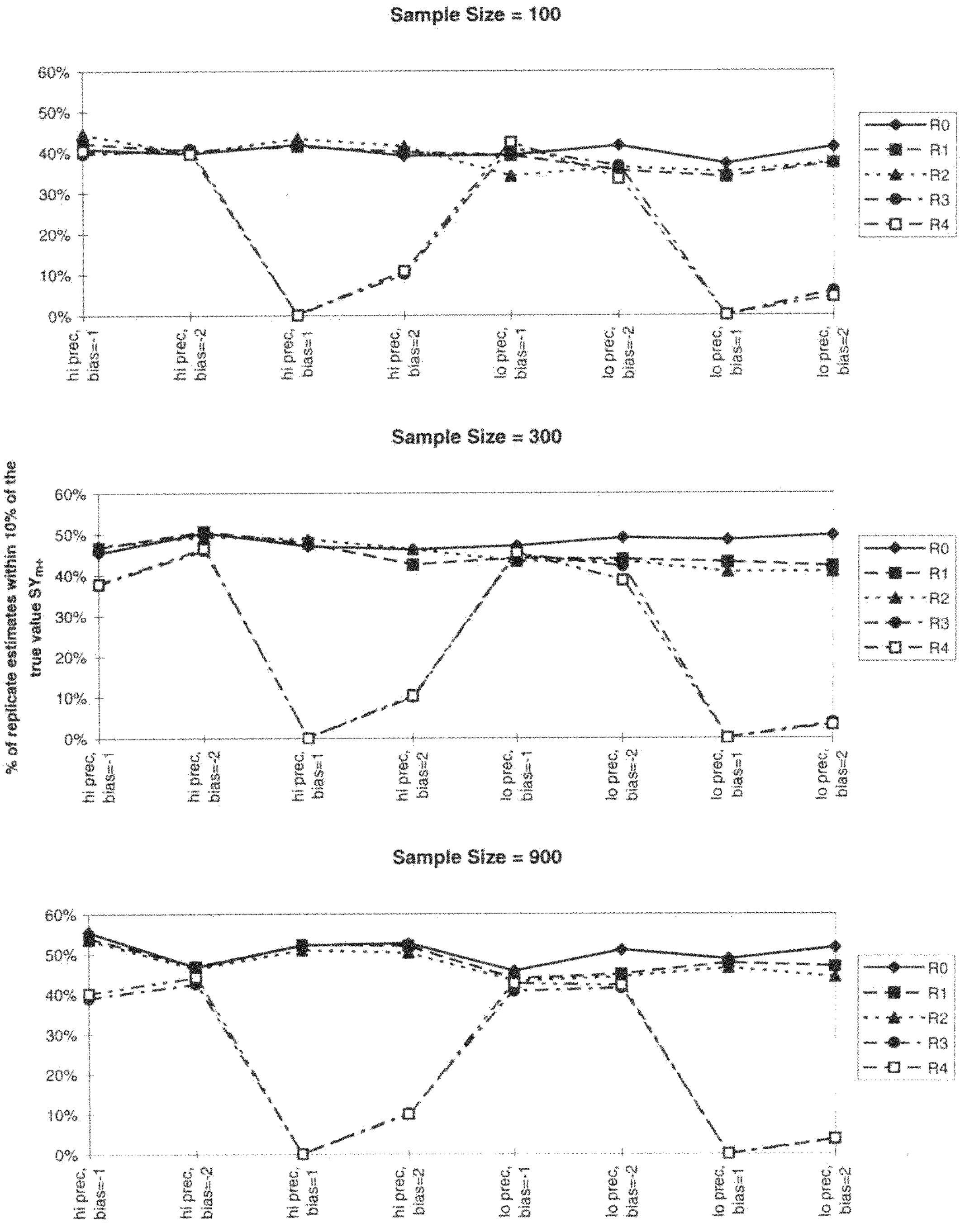


Figure 3.14 Proportion of Monte Carlo replicates that produced estimates of SY_{m+} that were within 10% of the true value in scenario 1 with sample sizes 100, 300, and 900.

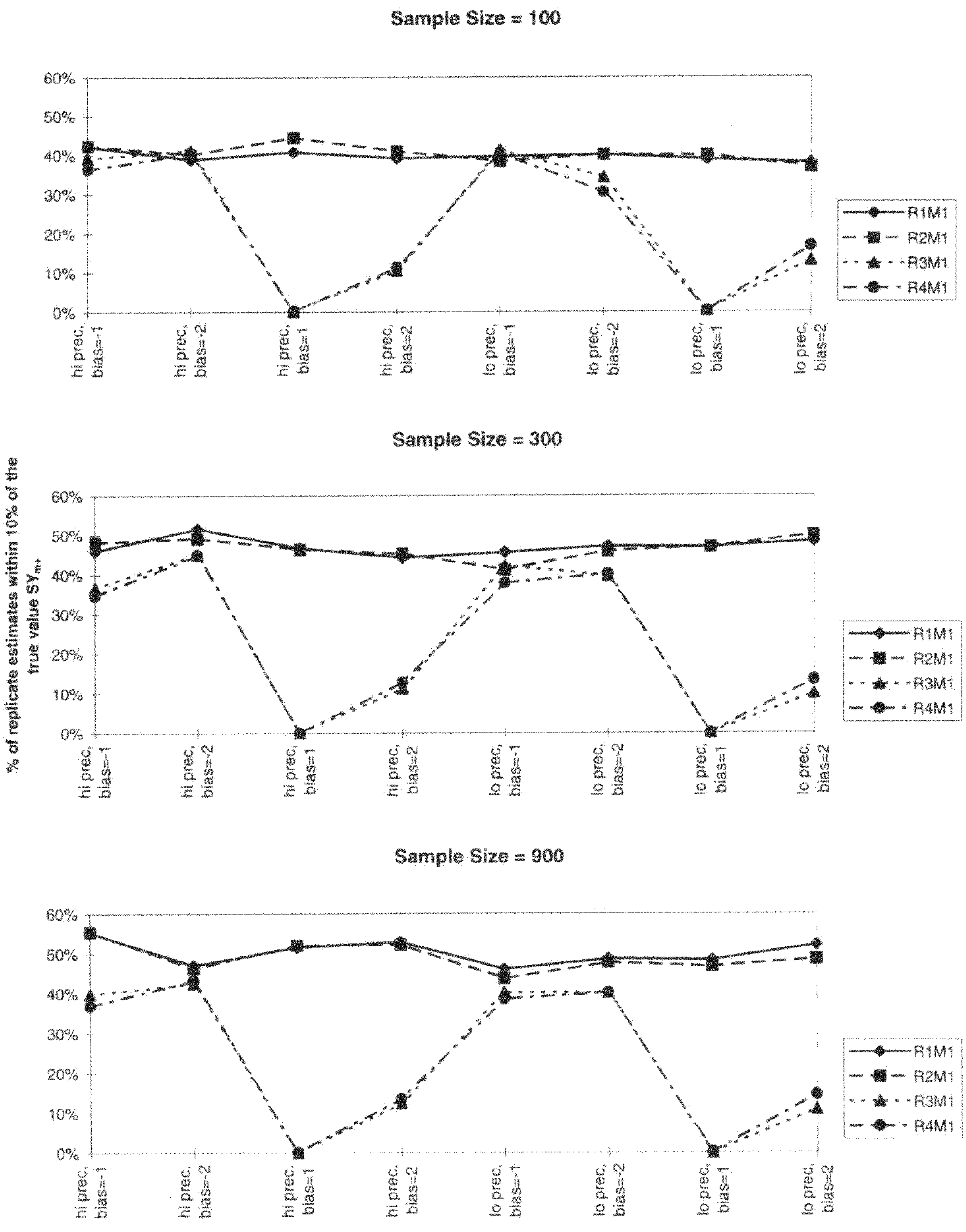


Figure 3.15 Proportion of Monte Carlo replicates that produced estimates of SY_{m+} that were within 10% of the true value in scenario 2a with sample sizes 100, 300, and 900.

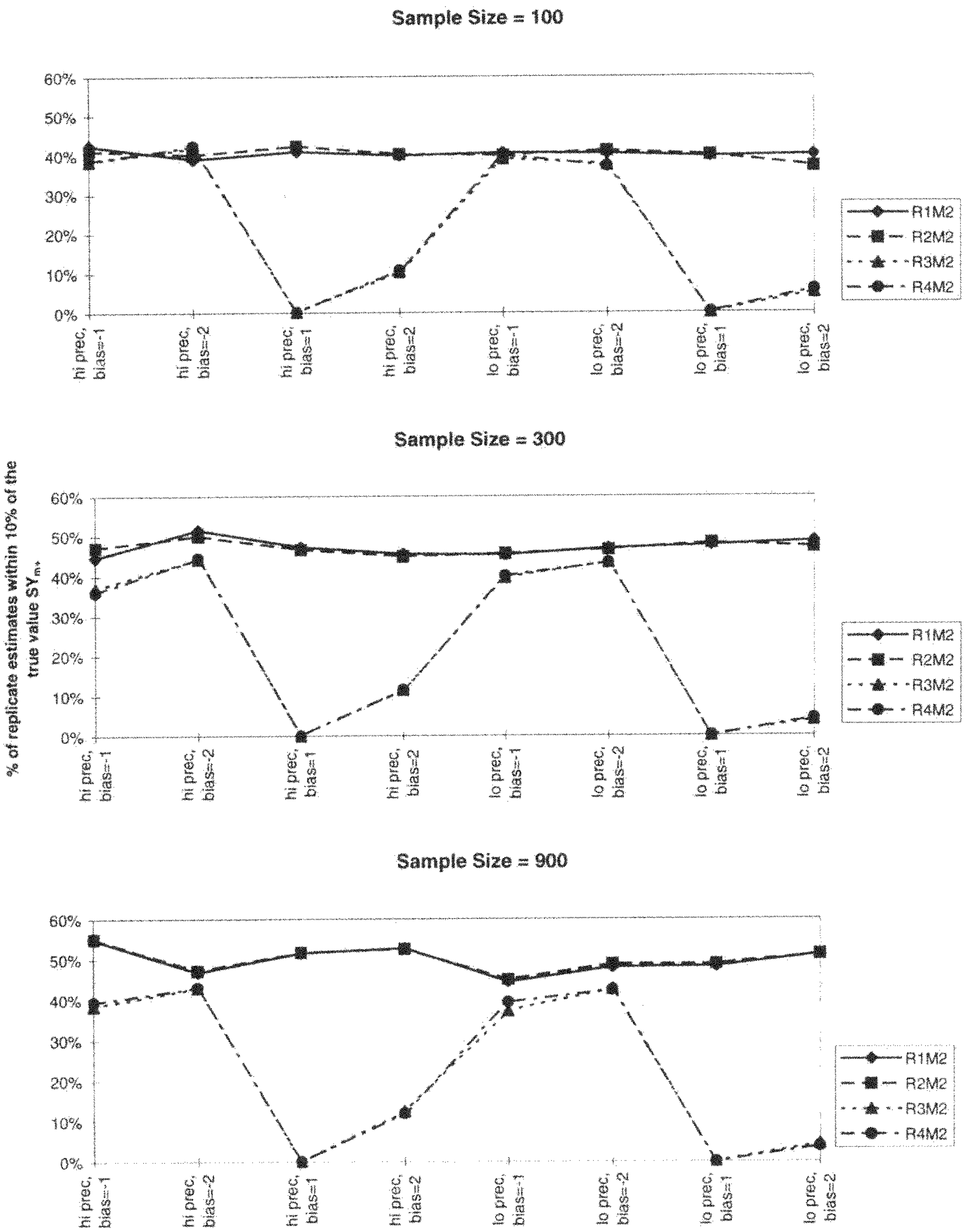


Figure 3.16 Proportion of Monte Carlo replicates that produced estimates of SY_{m+} that were within 10% of the true value in scenario 2b with sample sizes 100, 300, and 900.

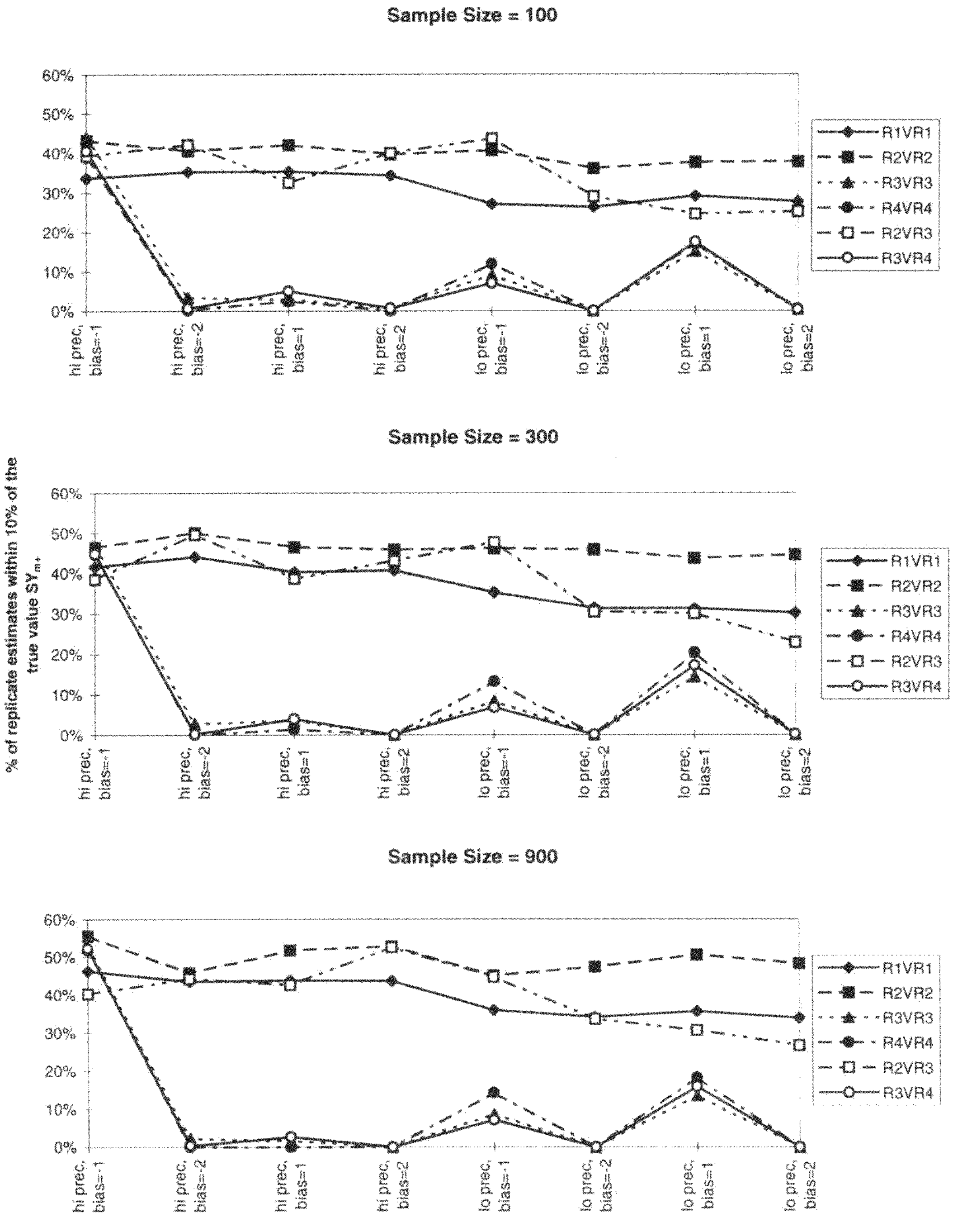


Figure 3.17 Proportion of Monte Carlo replicates that produced estimates of SY_{m+} that were within 10% of the true value in scenario 3 with sample sizes 100, 300, and 900.

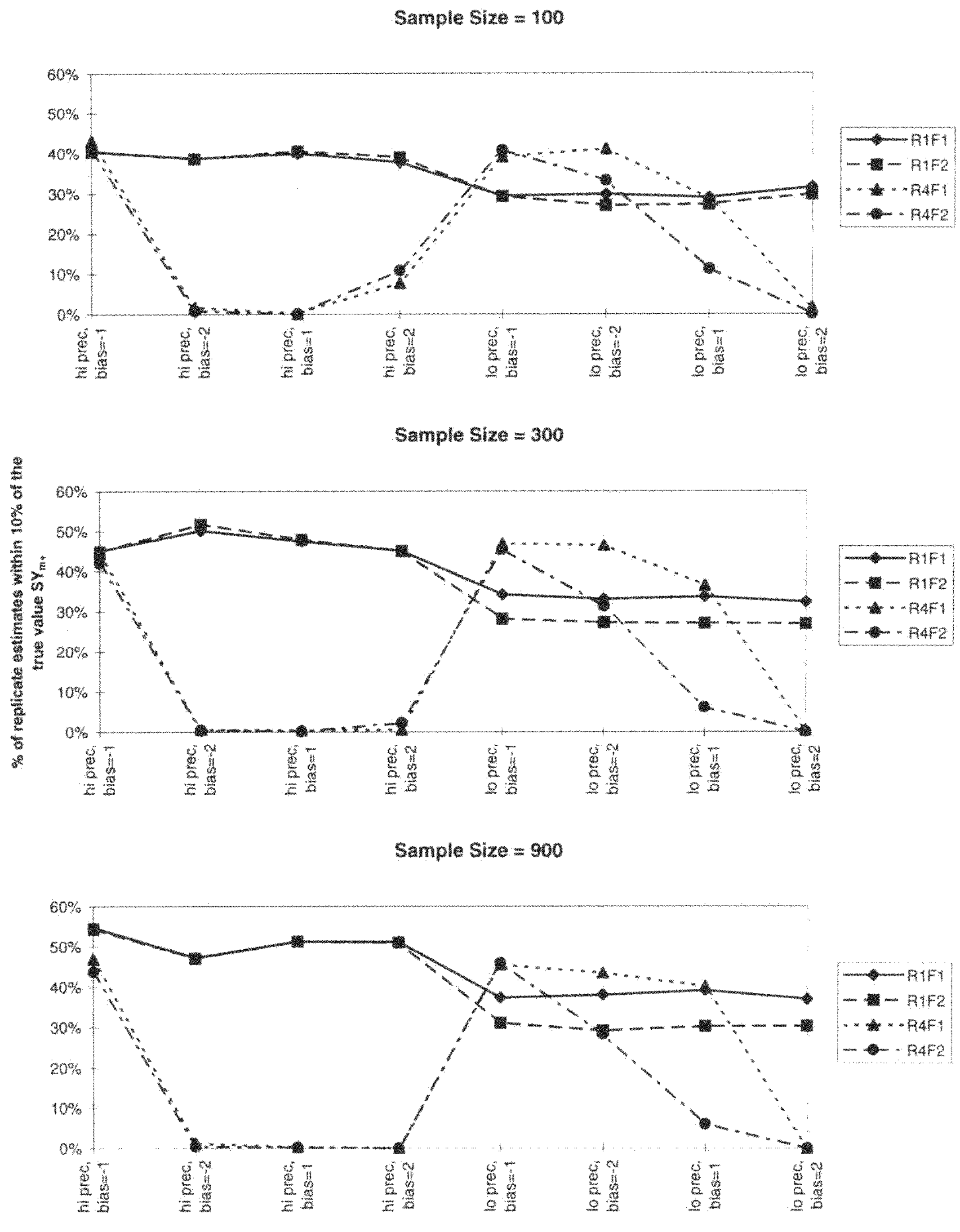


Figure 3.18 Proportion of Monte Carlo replicates that produced estimates of SY_{m+} that were within 10% of the true value in scenarios 4a and 4b with sample sizes 100, 300, and 900.

R0, R1, and R2 readers and ranged between approximately 38% to 45%, 45% to 53%, and 45% to 56% for sample sizes of 100, 300, and 900, respectively (Figures 3.14-3.16). The proportion of accurate estimates from the R3 or R4 readers was uniformly zero for the bias = 1 case among scenarios 1, 2a, and 2b with all sample sizes.

In scenario 3, proportions ranged from 0% to 45%, 0% to 50%, and 0% to 55% among all reader types and sample sizes of 100, 300, and 900, respectively (Figure 3.17). When employing the R2VR2 combination of reader types in scenario 3, the highest proportions were produced ranging from 40% to 42%, 48% to 51%, and 46% to 56% for sample sizes of 100, 300, and 900 respectively.

In scenarios 4a and 4b with the R1 reader type, proportions ranged from approximately 26% to 40%, 30% to 53%, and 33% to 55% for sample sizes of 100, 300, and 900, respectively (Figure 3.18). The R4 reader type produced highly variable results in scenarios 4a and 4b with probabilities ranging from 0% to 42%, 0% to 48%, and 0% to 48%, among sample sizes of 100, 300, and 900, respectively.

The general trend supported by these results is similar to SY_{ST} in that increasing sample size results in decreasing the CV of sustained yield estimates but can either increase or decrease the probability of obtaining an accurate estimate. However, the estimation of SY_{m+} is apparently more robust than SY_{ST} considering ageing imprecision since the probability of obtaining an accurate estimate increases only if the catch-age composition is being estimated an unbiased reader type(s).

Reader Types

The relative performance of some reader types was initially puzzling when considering the results of this study. Most notably was the poor performance of the R1VR1 reader combination compared to the R2VR2 reader combination in scenario 3. However, this result is explained by recalling how disagreements among intermediate observed ages were reconciled.

The R1VR1 situation was a scenario where the intermediate ages from two expert readers were being compared. Since neither was defined as "more expert", the rounded mean of the intermediate ages was assigned as final observed age when there was a disagreement. Therefore, if the intermediate ages differ by one year, the older age is used (e.g. 4 and 5, mean is 4.5, final observed age is 5). If the intermediate ages differ by 2 years, the mean is used (e.g. 4 and 6, mean and final observed age is 5). If the intermediate ages differ by three years, an age older than the mean is used (e.g. 4 and 7, mean is 5.5, final observed age is 6). This pattern illustrates that the final observed age from two expert readers is actually positively biased if non-equal intermediate ages are reconciled with rounded means.

The other curious result was that in general, the R2 reader performed better than the R1 reader. This can be explained by recalling that difference between the R1 and R2 reader types is that the R1 reader has a constant standard deviation of observed age as a function of true age, and that the R2 reader type has an increasing standard deviation of observed age as a function of true age. Additionally, because of the truncation in the classification matrix that takes place at the upper age bound, the R2 reader has a greater probability of under-ageing the oldest aged fish than does the R1 reader type. In effect this causes the population to appear slightly more productive and elevates the estimate of sustained fishing mortality and sustained yield slightly for the R2 type reader.

Ageing Scenarios

It is clear from the results of this study that the deleterious effects of ageing bias were not mitigated by the multiple readings among and between readers within scenarios 2, 3 and 4. It is also apparent that the effects of ageing imprecision can be mitigated to some extent by multiple readings. Comparisons of the extant relative error in the estimated value of SY_{ST} and SY_{m+} among ageing scenarios under the low precision case suggest that scenarios 2a and 2b were the most effective at reducing bias in estimating sustained yield. Furthermore, it does not appear that either disregarding structures without a modal age (scenario 2a) or assigning the median of replicate readings (scenario 2b) are clearly superior. There is some suggestion in considering the results of the R1F readers in scenario 4 that under low precision it may be preferable to disregard structures with non-modal ages rather than assigning medians. However, it is also clear that scenario 2 performs better than scenario 4 given unbiased reader types based on trends in relative error.

3.3 Lambda (λ_s) Evaluation

As described in the methods section, a limited sensitivity analysis was conducted to examine the effect of varying the value of the weighting parameter (λ_s) on sustained yield estimates. Tables 3.8 and 3.9 report the estimated relative error and coefficient of variation of estimates of SY_{ST} and SY_{m+} among simulation runs with sample sizes of 100, 300, and 900 under low precision and bias = -2. The simulations with λ_s specified as 100 generally show increased relative error and decreased precision (increased CV). The results of this analysis indicate that ageing error can influence the estimation of sustained yield as a function of λ_s, with less weighting on the survey data (smaller λ_s) causing greater error in sustained yield due to ageing error. The trend described above is generally true, but some reader types are affected to a greater degree than others. For example, the effect on the estimates from the R0 reader type is not nearly as substantial as the effect on the resultant estimates from the R3VR3 reader types.

Table 3.8 Relative error and coefficient of variation of estimates of SY_{ST} under low precision and bias = -2 among reader type(s)/scenarios for two values of the survey weighting parameter (λ_s).

Relative error of SY_{ST} among reader(s)/scenarios.

	λ_s = 1300			λ_s=100		
	Sample Size			Sample Size		
Reader(s)/Scenario	100	300	900	100	300	900
R0	-2%	-4%	-2%	-5%	-5%	-4%
R1	-36%	-34%	-33%	-50%	-47%	-48%
R2	-38%	-36%	-35%	-52%	-50%	-50%
R3	22%	26%	31%	4%	14%	19%
R4	15%	19%	24%	-3%	7%	10%
R1M1	-17%	-15%	-13%	-30%	-26%	-25%
R2M1	-10%	-6%	-4%	-21%	-16%	-15%
R3M1	21%	26%	32%	0%	11%	16%
R4M1	21%	26%	32%	2%	13%	19%
R1M2	-13%	-11%	-10%	-24%	-20%	-21%
R2M2	-15%	-12%	-11%	-26%	-22%	-22%
R3M2	29%	32%	38%	8%	19%	24%
R4M2	25%	28%	34%	5%	15%	19%
R1VR1	-44%	-43%	-43%	-57%	-55%	-55%
R2VR2	-32%	-30%	-29%	-45%	-42%	-42%
R3VR3	-89%	-89%	-88%	-99%	-99%	-100%
R4VR4	-84%	-84%	-83%	-96%	-96%	-96%
R2VR3	-43%	-41%	-40%	-59%	-56%	-56%
R3VR4	-90%	-90%	-89%	-99%	-100%	-100%
R1F1	-28%	-31%	-30%	-39%	-39%	-39%
R1F2	-37%	-40%	-40%	-48%	-49%	-49%
R4F1	6%	10%	13%	-3%	4%	6%
R4F2	38%	42%	45%	36%	46%	48%

Estimated value of the CV of SY_{ST} among reader(s)/scenarios.

	Sample Size			Sample Size		
Reader(s)/Scenario	100	300	900	100	300	900
R0	36%	25%	23%	39%	26%	20%
R1	36%	27%	24%	41%	29%	22%
R2	35%	27%	24%	41%	29%	22%
R3	28%	22%	22%	33%	24%	19%
R4	28%	22%	22%	34%	24%	19%
R1M1	37%	27%	24%	40%	28%	21%
R2M1	35%	27%	24%	40%	28%	21%
R3M1	29%	23%	22%	39%	26%	19%
R4M1	30%	23%	22%	40%	27%	20%
R1M2	35%	26%	24%	38%	27%	21%
R2M2	34%	26%	24%	37%	27%	21%
R3M2	27%	22%	22%	34%	24%	18%
R4M2	28%	22%	22%	33%	24%	18%
R1VR1	44%	30%	26%	45%	31%	23%
R2VR2	36%	26%	24%	39%	28%	21%
R3VR3	47%	36%	32%	176%	140%	127%
R4VR4	41%	30%	28%	85%	56%	33%
R2VR3	34%	26%	24%	41%	28%	21%
R3VR4	51%	37%	34%	189%	184%	192%
R1F1	44%	29%	24%	47%	31%	23%
R1F2	42%	28%	25%	44%	29%	22%
R4F1	31%	24%	22%	38%	27%	20%
R4F2	30%	22%	22%	33%	25%	20%

Table 3.9 Relative error and coefficient of variation of estimates of SY_{m+} under low precision and bias = -2 among reader type(s)/scenarios for two values of the survey weighting parameter (λ_s).

Relative error of SY_{m+} among reader(s)/scenarios.

λ_s = 1300

Reader(s)/Scenario	Sample Size 100	300	900
R0	-2%	-4%	-3%
R1	-9%	-9%	-8%
R2	-11%	-10%	-9%
R3	-9%	-8%	-5%
R4	-12%	-11%	-8%
R1M1	-3%	-3%	-2%
R2M1	-1%	1%	2%
R3M1	-10%	-9%	-6%
R4M1	-11%	-10%	-7%
R1M2	0%	0%	1%
R2M2	-1%	-1%	0%
R3M2	-6%	-5%	-3%
R4M2	-8%	-7%	-5%
R1VR1	-14%	-15%	-14%
R2VR2	-8%	-7%	-7%
R3VR3	-64%	-64%	-64%
R4VR4	-60%	-61%	-60%
R2VR3	-16%	-15%	-15%
R3VR4	-64%	-65%	-65%
R1F1	-10%	-13%	-12%
R1F2	-13%	-17%	-16%
R4F1	2%	2%	4%
R4F2	13%	14%	16%

λ_s=100

Reader(s)/Scenario	Sample Size 100	300	900
R0	-3%	-4%	-3%
R1	-18%	-16%	-16%
R2	-19%	-17%	-17%
R3	-17%	-12%	-10%
R4	-20%	-15%	-14%
R1M1	-10%	-7%	-7%
R2M1	-6%	-3%	-3%
R3M1	-21%	-15%	-12%
R4M1	-21%	-15%	-12%
R1M2	-7%	-4%	-4%
R2M2	-7%	-5%	-5%
R3M2	-16%	-10%	-8%
R4M2	-18%	-12%	-10%
R1VR1	-22%	-20%	-20%
R2VR2	-16%	-14%	-13%
R3VR3	-78%	-77%	-77%
R4VR4	-73%	-72%	-72%
R2VR3	-26%	-23%	-23%
R3VR4	-78%	-78%	-78%
R1F1	-17%	-17%	-17%
R1F2	-19%	-21%	-21%
R4F1	-4%	0%	1%
R4F2	12%	16%	17%

CV of SY_{m+} among reader(s)/scenarios.

Reader(s)/Scenario	Sample Size 100	300	900
R0	21%	16%	15%
R1	19%	16%	15%
R2	18%	16%	15%
R3	20%	17%	17%
R4	20%	17%	17%
R1M1	20%	16%	16%
R2M1	19%	16%	16%
R3M1	21%	18%	18%
R4M1	21%	18%	18%
R1M2	20%	16%	16%
R2M2	19%	16%	16%
R3M2	20%	17%	17%
R4M2	20%	17%	18%
R1VR1	22%	17%	16%
R2VR2	19%	16%	15%
R3VR3	18%	16%	16%
R4VR4	18%	16%	16%
R2VR3	18%	15%	15%
R3VR4	18%	16%	16%
R1F1	23%	17%	16%
R1F2	22%	16%	15%
R4F1	18%	16%	16%
R4F2	18%	16%	16%

Sample Size Reader(s)/Scenario	Sample Size 100	300	900
R0	22%	17%	14%
R1	19%	17%	15%
R2	19%	16%	14%
R3	23%	18%	16%
R4	23%	19%	16%
R1M1	21%	17%	14%
R2M1	20%	17%	15%
R3M1	26%	19%	16%
R4M1	26%	21%	17%
R1M2	20%	17%	14%
R2M2	19%	17%	15%
R3M2	24%	19%	16%
R4M2	23%	19%	16%
R1VR1	21%	17%	14%
R2VR2	19%	17%	14%
R3VR3	24%	18%	16%
R4VR4	21%	17%	14%
R2VR3	19%	16%	14%
R3VR4	23%	19%	16%
R1F1	23%	18%	15%
R1F2	22%	17%	14%
R4F1	21%	18%	15%
R4F2	20%	17%	15%

DISCUSSION

4.1 Effects of Sample Size on Estimates of Sustained Yield

SY_{ST}

The effect of sample size on the expected value of SY_{ST} was of little consequence as demonstrated by the nearly perfect consistency of hypothesis test results among different sample sizes. This result suggests that attempting to mitigate bias in sustained yield estimates resulting from poor reader performance by increasing sample size is not a feasible tactic.

In contrast, sample size plays a major role in determining the variability of sustained yield estimates. It is apparent that the CV of sustained yield estimates and the probability of obtaining an estimate of sustained yield that is within 10% of the true value given a particular Monte Carlo replicate generally increases with increasing sample size. Kimura (1989a, 1990) reported a similar trend in the precision of biomass estimates from ASA models as a function of sample size. In this study, the CV of sustained yield estimates always decreased as sample size increased. However, the probability of obtaining an accurate estimate either increased, stayed nearly the same, or decreased slightly as sample size was increased depending on the reader type(s)/scenario. As the CV of the biased estimates were reduced, the portions of the distributions which were within 10% of the true sustained yield were reduced; in contrast, as the CV of the unbiased estimates were reduced the portions of the distributions that were within 10% of the true sustained yield were increased. These general trends imply that increasing sample size will result in increasing the probability of obtaining an accurate estimate only if the catch-age composition is being determined by a precise and unbiased reader.

The unexpected result that increasing sample size does not always increase the probability of obtaining an accurate estimate is probably also due to the effect of other information used in catch-age analysis, namely estimates of relative or absolute abundance. The weighting used for this other information can have a large effect on abundance estimation and hence obviate the influence of the ageing information. Furthermore, as sample size is increased, ageing bias and imprecision have greater deleterious affects on parameter estimation.

SY_{m+}

The effect of sample size on the expected value of SY_{m+} was very similar to that observed for SY_{ST}. Increasing sample size did not substantially affect the expected value of SY_{m+} nor affect the outcome of the hypothesis tests of the relative difference between the estimated value of SY_{m+} and the true value.

The variability in the estimated value of SY_{m+} was generally similar to the variability of SY_{ST}. The probability of obtaining an accurate estimate for the R0, R1, and R2 reader types increased consistently with increases in sample size. This result was slightly different from the results for SY_{ST}, in which the probability of obtaining an accurate estimate using the R1 and R2 type readers under low precision did not increase as a function of sample size. The biased R3 and R4 reader types display an inverse relationship between the probability of obtaining an accurate estimate and the sample size, because believing no bias with data of high precision leads to erroneous confidence in data and misleading results. The general trend observed for the variability of SY_{ST} is mimicked by the variability of SY_{m+} with the exception that even under the low precision case, increasing sample size tends to increase the probability of obtaining an accurate estimate in the absence of ageing bias.

4.2 Effects of Ageing Error on Estimates of Sustained Yield

SY_{ST}

The effects of ageing error on the estimated value SY_{ST} were more pronounced than the effects of sample size. Furthermore, ageing bias tends to have greater effect on estimates of sustained yield than ageing precision. In general, negative ageing bias tended to produce positively biased estimates of SY_{ST} and positive ageing bias tended to produce negatively biased estimates of sustained yield. This result is similar to the findings published by other researchers studying the effects of ageing error on ASA and yield-per-recruit models (Kimura 1990, Rivard 1983, Tyler et al. 1989, and Lai and Gunderson 1987).

Under-estimation of fish age is prevalent using scales and whole otoliths for some species of fish (Chilton and Stocker 1987, Lentsch and Griffith 1987, Pikitich and Demory 1988, Sharp and Bernard 1988, Booth et al. 1995, Polat and Gumus 1996). There are a variety of mechanisms which may cause this to occur including undetectable first year annuli on scales or whole otoliths, and compression of annuli near scale margins. These conditions can result in under-ageing across the entire lifespan, under-ageing at older ages, or under-estimation of longevity. Therefore, when employing age-structured models it is critical to utilize structures that do not consistently bias fish age. In particular, structures which inherently under-age fish should be avoided since negative bias has been shown to result in non-conservative management recommendations.

The effect of increasing ageing imprecision on the expected value of SY_{ST} was to decrease the expected value of SY_{ST}. This result was particularly evident given the unbiased R1 and R2 reader types among all scenarios. This is a heartening result for fisheries managers since it suggests that increasing ageing imprecision results in more conservative management strategies. Furthermore, in the case of the biased R3 and R4 reader types, the effect of ageing imprecision caused the expected value of SY_{ST} to be less biased given negative ageing bias in the low precision case versus the high precision case because of the offsetting trends of negative ageing bias and low ageing precision.

SY_{m+}

The effect of ageing error on estimates of the estimated value of SY_{m+} often followed the observed trends in the expected value of SY_{ST}. However, the magnitude of the relative errors in SY_{m+} imposed by ageing error were substantially less. Ageing bias again had a larger effect on SY_{m+} than ageing precision. Additionally, as with SY_{ST}, negative ageing bias caused positive relative error in SY_{m+}, and positive ageing bias caused negative relative error in SY_{m+}. This result is due to either the over-estimation of selectivity of age

2 fish (greater than 1), in the case of negative ageing bias, or to an error in the specification of the youngest age recruited to the fishery, in the case of positive ageing bias. To illustrate, recall that the estimation of F_{m+} is solely dependent on selectivity-at-age and natural mortality. Under negative ageing bias, the selectivity of two year old fish was over-estimated resulting in an under-estimate of F_{m+}. However, because of over-estimation of selectivity of age 2 fish, the effective fishing mortality on age 2 fish was larger than the full recruit fishing mortality resulting in the over-estimation of SY_{m+}. Indeed, this result is counterintuitive considering that negative ageing bias resulted in negative relative error for both F_{m+} and projected abundance and is the result of allowing estimated selectivity to exceed 1 in the CAGEM analysis.

Given a positive ageing bias, the estimated catch-age composition ranges from 3 to 7+ and 4 to 7+ for ageing biases of +1 and +2, respectively. In turn, the CAGEM and catch-per-recruit of fully mature fish analyses are conducted based on these age ranges and the assumption that selectivity is equal to one for all age classes. The resulting F_{m+} estimates are 0.221 and 0.293 for ageing biases of +1 and +2, respectively. The only variability in the estimates of SY_{m+} was therefore related to the estimation of projected abundance which was severely negatively biased.

Ageing imprecision had far less effect on the expected value of SY_{m+} than on the expected value of SY_{ST}. Thus, the estimation of F_{m+} is apparently more robust to the levels of ageing imprecision specified in the simulations since the estimated projected abundance and selectivity of age 2 fish are identical in the calculation of SY_{ST} and SY_{m+}.

4.3 Effects of Lambda (λ_s) on Estimates of Sustained Yield

The limited sensitivity study of the effect of the weighting parameter (λ_s) revealed that a change in λ_s did indeed change the relative error in sustained yield estimates. Furthermore, it affected the relative error of sustained yield for some reader types more than others. This is not surprising considering that the definition of the optimum value of λ_s is the ratio of the catch variance and the survey variance (Deriso et al. 1985, 1989). Obviously, since the variability in the catch is a function of ageing error, the optimum value of λ_s would differ by reader type.

This result strengthens Kimura's (1989b) contention that constraints, including the value of λ_s, can and should be applied systematically to assess the overall variability in model performance. This is especially true when one does not know the relative amounts of variability in catch data versus survey data, as is usually the case. Multiple values of λ_s should be used to discover a weighting value which both maximizes model fit and minimizes trends in catch residuals.

4.4 Effects of Model Structure on Estimates of Sustained Yield

By definition, the structure of a model affects output and hence implications drawn from its use. Recall that in program AGEERR the introduction of ageing error was a two-step process: (1) incorporating imprecision as a function of true age using a classification matrix and (2) given a biased reader type, adding a constant bias. When incorporating ageing error due to imprecision, the process prohibited the resultant observed age from traversing the true age range. Furthermore, when subsequently incorporating ageing bias, the resultant observed age was again restricted to the true age range. As a result, under negative ageing bias, the biased R3 and R4 reader types produced age compositions ranging from 2 to 9 (bias of -1) or 2 to 8 (bias of -2). After the incorporation of the plus group, the age ranges considered in the catch-age analysis are 2 to 7+ for both -1 and -2 biases, and the resultant catch-at-age was highly skewed towards age 2 fish. The net effect on parameter estimates was to grossly over-estimate the selectivity of age 2 fish, and to under-estimate the projected abundance.

Under positive ageing bias, the biased R3 and R4 reader types produced age compositions ranging from 3 to 10 (bias of +1) or 4 to 10 (bias of +2). After the incorporation of the plus group, the age ranges considered in the catch-age analyses were 3 to 7+ (+1 bias) and 4 to 7+ (+2 bias). Furthermore, since the simulation assumed that all ages >2 were fully recruited, the catch-age analysis did not estimate any selectivity coefficients. The net effect was to cause even larger under-estimation in the projected abundance than experienced under negative ageing bias.

It could be argued that the strategy of incorporating ageing bias in program AGEERR is unrealistic and that the effects on parameter estimates are artifacts of the simulation. An alternative strategy for modeling ageing error is to specify bias directly in the transition matrix (Tyler et al. 1989, Bradford 1991, Rivard 1983). Additionally, one could specify a variable bias as a function of age. A third strategy could be to specify a constant bias throughout the age range but allow observed age to traverse the age range. One could then disregard all observed ages outside the true age range. It is suspected that all these strategies would produce similar trends in the relative error of sustained yield, because the same changes in the distribution of ages would occur. It is possible that results from this study are more extreme than would be results produced using alternate methods of modeling ageing error. However, the focus of this research was to point out the relative trends caused by sampling and ageing error rather than to predict absolute error. Indeed, it is nearly impossible to model all the vagaries found in estimating the age of fishes, and the conclusions drawn from this study can be viewed as a worst case scenario with obvious implications to management.

4.5 Conclusions

The general conclusions regarding the effect of sample size and ageing error on estimates of sustained yield from the QS model are as follows:

1. Sample size does not significantly affect the expected value of sustained yield. Sample size does affect the variability of estimates of both SY_{ST} and SY_{m+}. Increases in sample size result in increasing the probability of obtaining an accurate estimate of SY_{ST} only when catch-age composition is estimated by a precise and unbiased reader. Increases in sample size result in increasing the probability of obtaining an accurate estimate of SY_{m+} only when catch-age composition is estimated by an unbiased reader.

2. Ageing error affects the estimated value of both SY_{ST} and SY_{m+}. Positive ageing bias generally results in the under-estimation of both SY_{ST} and SY_{m+}, and negative ageing bias generally results in the over-estimation of both SY_{ST} and SY_{m+}. In the absence of ageing bias, a high degree of ageing imprecision generally results in the under-estimation of both SY_{ST} and SY_{m+}. The net effect in terms of management implications is that both positive ageing bias and ageing imprecision tend to result in conservative management recommendations, and that negative ageing bias tends to result in non-conservative management recommendations.

3. The most effective ageing procedure to reduce the affect of ageing imprecision is to use modal ages resulting from three intermediate readings from a single reader. There is little difference in terms of resultant estimates of sustained yield among

the procedures of disregarding non-modal ages or assigning the median of intermediate ages.

4. The value of the weighting parameter λ_s, is critical in determining bias in estimates of sustained yield considering the QS model. The influence of λ_s increases with the amount of error in the catch-at-age data.

5. Finally, this study emphasizes the importance of careful validation of ageing techniques. Common problems encountered in determining the age of fish are: (1) measurement error (imprecision) caused by poor ageing judgment and ability (e.g. readers failing to recognize all the extant annuli in structures collected from older fish); and (2) process error due to annuli not being formed [e.g. missing first year annuli in some rainbow trout (Lentsch and Griffith 1987)]. Since imprecision and bias can act in different directions, it is unclear what the resultant effect on estimates of sustained yield will be. Only by careful experimentation and development of ageing protocols will it be possible to validate estimates of sustained yield when ageing error is present.

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APPENDIX A. USERS MANUAL FOR PROGRAM AGEERR

Age-structured assessment methodology or catch-age analysis is emerging as the dominant stock assessment procedure. The method synthesizes age structure, surveys, catch, and other types of data to provide information on population parameters. This information can then aid in the realization of management objectives. However, catch-age analysis is susceptible to many of the pitfalls associated with other analyses. For example, ageing error is frequently assumed to be negligible when conducting catch-age analysis. This assumption is usually unfounded and the effect of the ageing error on the results of the catch-age analysis can be substantial.

Program AGEERR is a Monte Carlo type simulation program designed to investigate the effects of sample size and ageing error on catch-age analysis and subsequent sustained yield estimation of an exploited age-structured fish population. The program contains four procedures: (1) generation of an exploited age structured fish population with associated true catch- and abundance-at-age; (2) construction of observed catch-at-age data by incorporating measurement error due to sampling, ageing error, and variability in the total catch; (3) estimation of population parameters using catch-age analysis with auxiliary information analysis and observed catch-at-age and auxiliary observed survey data; and (4) estimation of sustained yield.

The execution of the program is controlled by input parameters read from two command files (AGEERR.CMD and CAGEM.CMD; Appendix B1 and B2). The program expects input parameters in the order shown in the command files with the number of Monte Carlo trials specified in the first line of the input file AGEERR.CMD.

A.1 Generation of the True Population

Program AGEERR accepts a set of population parameters specific to the population under investigation and generates a time series of true catch- and abundance-at-age. This is accomplished using the typical Baranov catch equations (Baranov 1918; Appendix C1). The user should note that separable fishing mortality (Doubleday 1976, Deriso et al. 1985, 1989, Fournier and Archibald 1982, Pope 1977, and Pope and Shepherd 1982) is assumed (Appendix C1, equation 6). The required set of input parameters include: (1) the starting and ending years of the time series; (2) the true recruitment age of the population; (3) the oldest true age in the population; (4) the true abundance of all age classes in the starting year; (5) the true abundance of the recruitment age class in all years of the time series; (6) the true selectivity coefficients of all age classes; (7) the true natural mortality experienced by the population; and (8) the true full recruitment fishing mortality for each year of the time series. A flowchart describing this procedure is shown in Appendix B3. A single output file (AGEOUT.OUT) is generated during this procedure which contains the time series of the true abundance-at-age, catch-at-age, and selectivities (Appendix B4).

A.2 Observed Catch-at-Age Data

Program AGEERR randomly draws a specified number of samples without replacement from the true annual catch-at-age with the probability of selecting a fish of a given true age equal to the true proportion of that age class in the annual catch. If the specified sample size is larger than the annual catch, the program will stop and notify the user of the problem. The annual age composition of the sample is then estimated according to combinations of reader types and ageing scenarios which impart differing levels and types of ageing error (Appendix C2). The reader types represent different kinds of within-reader error: reader R0 is the perfect reader, reader R1 is precise and unbiased, reader R2 is imprecise and unbiased, reader R3 is precise and biased, and reader R4 is imprecise and biased. The ageing scenarios represent different ways in which ageing error due to ageing imprecision and between reader bias could be minimized. For example, two R3 readers working in a lab which employs multiple readings according to ageing scenario 2a would potentially produce sample age compositions much more similar than if they worked in a lab which employed only single readings as in scenario 1.

The 23 combinations are: scenario 1 with reader types R0, R1, R2, R3, and R4; scenario 2a with reader types R1, R2, R3, and R4; scenario 2b with reader types R1, R2, R3, and R4; scenario 3 with reader types R1 vs. R1, R2 vs. R2, R3 vs. R3, R4 vs. R4, R2 vs. R3, and R3 vs. R4; scenario 4a with reader types R1 vs. R1 and R4 vs. R4; and scenario 4b with reader types R1 vs. R1 and R4 vs. R4. Of the 23 age compositions, 22 are constructed given ageing error and one (scenario 1, reader R0) is constructed with no error.

Following Richards et al. (1992), classification matrices are used for each reader to assign observed age a given a true age b. The distribution of observed age given true age is discrete normal with expected value equal to the true age and variance defined by the ageing precision parameters specified in the model (Appendix C3). The user should note that although the observed age a will be assigned true age b with highest probability given the "unbiased" readers R1 and R2, these readers cannot be considered truly unbiased because the observed age must lie within the age bounds that the fish is recruited to the fishery. In other words, if fish younger than age 2 are never observed in the fishery, the observed age of a fish with true age 2 will always be greater than or equal to 2. A similar argument can be made for the oldest age fish. Therefore, observed age will always over-estimate the age of young fish and under-estimate the age of old fish. Additionally, given the introduced bias of readers R3 and R4, a negative bias will cause the observed ages from an R3 or R4 reader to be more accurate than an R1 or R2 reader for young fish. Similarly, a positive bias will cause the observed ages from an R3 or R4 reader to be more accurate than an R1 or R2 reader for old fish.

The final step in constructing the observed catch-at-age is to apply the observed annual age composition to the annual catch (Appendix B5). However an additional source of error is included here by assuming that the observed annual catches differ from the true annual catches according to a specified coefficient of variation (Appendix C3).

The input parameters necessary to generate the observed catch-at-age data include: (1) annual sample size (n); (2) standard deviations (σ_r, σ_A) of observed age given true age at recruitment (r) and the oldest age (A) (for the variable ageing precision of reader types R2 and R4); (3) α, the non-linearity parameter ($\alpha \neq 0$ if the three parameter ageing error model is used, enter 0 if the two parameter model is used); (4) constant standard deviation (σ) of observed age given true age (for the constant ageing precision of reader types R1 and R3); (5) the constant bias of readers R3 and R4; (6) pooling age if a plus age class is to be used, enter 0 if pooling is not performed; and (7) the coefficient of variation of the observed total annual catch estimate.

A total of nine output files are generated during this procedure. The first 8 files named: R0.OUT, SCEN1.OUT, SCEN2R1.OUT, SCEN2R2.OUT, SCEN2R3.OUT, SCEN2R4.OUT, SCEN3.OUT, and SCEN4.OUT, are intermediate files and contain the true and observed ages for each fish sampled by reader type within each scenario. The last file, SAMSIZE.OUT, contains the replication specific sample size used in determining the observed age composition for each reader/scenario type (Appendix B6).

A.3 Catch-Age Analysis with Auxiliary Information

Catch-age analysis with auxiliary information is performed within program AGEERR using a variant of program CAGEAN (Deriso et al. 1985, 1989) called program CAGEM. Program CAGEM assumes a multinomial-like measurement error structure appropriate for ageing error in the observed catch-at-age data. The relevant formulae for the objective function for parameter estimation with the multinomial-like measurement error structure and survey auxiliary data are given in Appendix C4. Additionally, the relevant formulae used to model the survey estimate of total exploitable abundance are also presented (equations 17-18). The overall structure of the analysis in terms of input and output data is shown in Appendix B7. All information supplied to the analysis are generated from within the program with the exception of: (1) natural mortality; (2) pooling parameter (1 if last age is pooled, 0 if no pooling); (3) survey lambda (λ_s); (4) the coefficient of variation of the survey data; and (5) the age of full selectivity. Of these, the first three are specified in the CAGEM.CMD file and the CV of the survey data and the age of full selectivity are specified in the AGEERR.CMD file.

An initial values file (INITS.DAT) is constructed within the program which supplies starting values for all the parameters to be estimated in the analysis (Appendix B8). These include: (1) the natural logarithm of population abundance-at-age during the first year; (2) the natural logarithm of recruit abundance during all years; (3) the natural logarithm of fishing mortality during all years; and (4) the natural logarithm of the selectivity of all age classes which are not fully recruited to the fishing gear. The initial values file contains the true values for all of the parameters except the fishing mortalities. The fishing mortalities are altered from the true value by adding a uniform random variate between 0 and 1 to the true value. True values are supplied in the initial values file in order to aid in convergence. However, to assure that non-linear search routine does not simply settle on the initial values, error is included in the fishing mortalities.

The auxiliary data are contained in the survey data file (SURVEY.DAT) which is constructed within the program (Appendix B9). In terms of the simulation it represents a time series of total exploitable abundance estimates (e.g. a mark-recapture experiment). The program also constructs a catch-at-age data file (CATCH.DAT) (Appendix B10). This is the primary input data file for each specific analysis by reader/scenario and contains the observed catch-at-age data from procedure 2.

A particular set of input parameters specific to a given reader/scenario type may produce a data set which causes undefined mathematical relationships to appear during the non-linear search routine for parameter estimation (e.g. ln (0) or divide by 0). If this occurs the program will jump out of the current analysis and begin the analysis for the next reader/scenario type within the current iteration. Therefore, all reader/scenario types may not have parameter estimates associated with each iteration.

A total of three output files are constructed during this procedure: CAGEM.LIS, CAGEMAB.LIS, AND CAGEMF.LIS. The CAGEM.LIS file contains the general

CAGEM output such as the initial and final parameter values and the details of the non-linear search procedure. The CAGEMAB.LIS file is the general abundance output file and contains the estimated abundance-at-age and selectivity-at-age. The CAGEMF.LIS file contains the estimated fishing mortality-at-age. These files report the results of the current or last catch-age analysis by reader/scenario and are updated as each analysis is completed. Therefore, examination of these files will reveal the details of only the ongoing or just finished analysis rather than all the analyses that have preceded it.

A.4 Estimation of Sustained Yield

The estimation of sustained yield is conducted according to methods developed by Quinn and Szarzi (1993). Sustained yield is estimated according to two separate management objectives, SY_{ST} and SY_{m+} . Both assume the population is exploited with a constant full-recruitment fishing mortality and that both early life survival and fecundity-at-age are constant. The first objective seeks to find the fishing mortality (F_{ST}) which will take the population to its steady long term equilibrium abundance and age composition. This is accomplished by finding the fishing mortality (F_{ST}) which causes the net reproductive value of an *r* year old fish (age at recruitment to the fishery) to equal 1. A simple interpretation of this equilibrium condition is that each fish recruited to the fishery will on average produce 1 recruit, and as such replaces itself. In the course of finding F_{ST}, it is necessary to estimate early life survival. This is accomplished by taking the mean of the annual estimates of early life survival since each annual estimate of early life survival is equally likely. Once F_{ST} is found, the sustained yield (SY_{ST}) in the year following the last year of the analysis is estimated. The relevant formulae for the estimation of F_{ST} and SY_{ST} are given in Appendix C5. The second objective seeks to find the fishing mortality (F_{m+}) which will produce the largest catch of $m+$ age (typically $m+$ is age of full maturity) and older fish on a per-recruit basis (Sissenwine and Shepherd 1987, Fletcher 1987). As with F_{ST} above, F_{m+} is used to estimate the sustained yield (SY_{m+}) in the year following the last year of the analysis. The relevant formulae are presented in Appendix C6.

Appendix B11 depicts the overall structure of the sustained yield estimation procedure. The program accepts fecundity-at-age and the age of full maturity (age $m+$) as input data read from the AGEERR.CMD file. If the catch-age analysis incorporates a plus age group, an additional parameter, fecundity of the plus age group, must be supplied to the program in order to estimate the sustained yield. A logical means of estimating this fecundity is to use a weighted average of the fecundity of the ages making up the plus group with weights equal to 1, exp(-Z), exp(-2Z), exp(-3Z),... with estimates of fishing mortality equal to the average fishing mortality applied to the modeled population. This weighting strategy will discount the fecundity contribution of the older ages proportional to their relative abundance in the plus group. If a plus group is not used in the catch-age analysis, a zero should be entered in the AGEERR.CMD file on the appropriate line.

A total of 46 output files are generated during this procedure and represent the final estimates from program AGEERR. These 46 files are composed of 23 files containing the results of the SY_{ST} objective over the 23 reader/scenario types, and the 23 files containing the results of the SY_{m+} objective over the 23 reader/scenario types (Appendix B12). The SY1*.OUT (SY_{ST}) output files report: F_{ST}, proj. abun. (the projected absolute abundance in the year following the last year of the analysis), SY_{ST}, $F_{mort1st}$ (the estimated fishing mortality during the first year of the analysis), $F_{mortlast}$ (the estimated fishing mortality during the last year of the analysis), $Abun_{1st}$ (absolute abundance in the first year), $Abun_{last}$ (absolute abundance in the last year), and the selectivity-at-age (Appendix B13). The SY2*.OUT (SY_{m+}) output files report F_{m+} and SY_{m+} (Appendix B14).

If in the course of solving for either F_{ST} or F_{m+} an undefined mathematical relationship occurs, the program will jump out of the solve routine, write a blank line in the output file, and begin performing the sustained yield estimation for the next reader/scenario type. It is therefore possible to inspect the output files and determine how many overall iterations produced viable estimates for each reader/scenario type.

A.5 Specifying Input Data of the True Population

As described in the previous sections, program AGEERR requires numerous input parameters to explore the sensitivity of sustained yield estimates given a particular population and ageing error. To acquire these data, the user should begin by generating baseline population parameter estimates using either program CAGEAN, program CAGEM, or a spreadsheet version of catch-age analysis. The result of this analysis will be estimates of abundance-at-age, recruitment, fishing mortality, and selectivity-at-age.

These parameters will be used to reconstruct the population under study within the program. The user should keep in mind that the modeled population must portray the actual population closely for any recommendations or conclusions regarding ageing error or sample size to be valid.

A.6 An Example in the Use of Program AGEERR

As an example of using program AGEERR, consider the Gulkana River arctic grayling population (*Thymallus arcticus*) studied extensively by Bosch (1995). A stock assessment program utilizing program CAGEAN was conducted on the mainstem Gulkana River. Results of the catch-age analysis were used to find F_{ST}, F_{6+}, SY_{ST}, and SY_{6+} following the methods of Quinn and Szarzi (1993).

The information used by Bosch (1995) to estimate sustained fishing mortality and sustained yield included the population parameter estimates generated by program CAGEAN as well as estimates of grayling fecundity-at-age (Appendix B15). Appendix B15 contains all the information program AGEERR requires to model this population and generate sustained yield. However, to simulate the population, the plus group abundance must be apportioned to the contributing age classes and the fecundity of the plus group must be estimated. Bosch (1995) estimated SY_{ST} and SY_{6+} assuming a longevity of 10 as will this analysis. To calculate the 7+ fecundity, the weighting scheme described above was used resulting in a 7+ fecundity of 4140. To apportion the 7+ abundance in the first year to ages 7, 8, 9, and 10, an average exponential decay similar to the fecundity calculation was used. Let:

$$N(a,1986) = N(7+,1986)\frac{e^{-((a-6)Z)}}{\sum_{i=1}^{4} e^{-(iZ)}} \quad ,$$

where:

$Z = \overline{F} + M$ and $\overline{F}$ is the average fishing mortality experienced by the population during 1986-1991.

The resulting abundances for the 7-10 age classes are presented in Appendix B15. The additional information required by program AGEERR is related to modeling ageing error, specifying error relating to estimating total catch and survey abundance, specifying a realistic lambda (λ_s) value, and dictating the number of replications to be conducted by the program.

To specify ageing error germane to grayling, a data set was constructed containing estimated ages of scales collected from grayling before and after a known time-at-large. These data were from grayling collected at Fielding Lake, and the Chatanika, Chena, Salcha, and Gulkana Rivers (Merrit and Fleming 1991, Bosch 1995). Because none of these readings were validated, it was assumed that the first reading was correct and the expected age of the second reading is the sum of the first reading and the time-at-large. The data were then sorted by expected age and the standard deviation of observed age was estimated for each expected age class (Appendix B16). Two curves corresponding to the two and three parameter cases of equation 8 (Appendix C3) were then fit to the data (Appendix B17). The three parameter case was used so that ageing imprecision could be specified non-linearly.

Program AGEERR requires specification of coefficients of variation (CV) representing the imprecision of both the survey total exploitable abundance estimate and the total catch estimate. Bosch (1995) reports the annual CV of estimated total exploitable abundance from a mark recapture study on mainstem Gulkana River grayling. The values range from 15% to 40% with an average of 22%. The average value was used for the simulation. An estimate of CV of total catch was not available so an arbitrary but realistic value of 5% was used.

The ratio of catch variability to survey variability (λ_s) was specified as 1300 based on program CAGEM simulations (Dr. Terrance J. Quinn, II, pers. comm.). Finally, the number of program replications was specified as 1000 as is typical in many Monte Carlo simulations and should give adequate statistical power.

Combining all of the input parameters and specifying them in the required format results in the input files presented in Appendix B18 and Appendix B19.

A.7 Literature Cited

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A.7 Literature Cited (Continued)

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APPENDIX B TABLES AND FIGURES RELATED TO PROGRAM AGEERR USERS MANUAL

Appendix B-1 The format of the AGEERR.CMD input file.

1000	replications	reps
1986	starting year	ly
1991	ending year	jy
0.3	natural mortality	m
2	Recruitment age	k
10	Last age	la
34253.0	age k abundance in year 1	abun(iage,1)
30311.0	age k+1 abundance in year 1	abun(iage,1)
23874.0	age k+2 abundance in year 1	abun(iage,1)
4540.0	age k+3 abundance in year 1	abun(iage,1)
2331.0	age k+4 abundance in year 1	abun(iage,1)
45.0	age k+5 abundance in year 1	abun(iage,1)
25.0	age k+6 abundance in year 1	abun(iage,1)
7.0	age k+7 abundance in year 1	abun(iage,1)
4.0	age la abundance in year 1	abun(iage,1)
41271.0	age k abundance in year 2	abun(k,2)
22390.0	age k abundance in year 3	abun(k,3)
46004.0	age k abundance in year 4	abun(k,4)
90218.0	age k abundance in year 5	abun(k,5)
16940.0	age k abundance in year ly-jy+1	abun(k,jy-ly+1)
0.187	Selectivity (la-k+1 values)	sel(a)
1.0		
1.0		
1.0		
1.0		
1.0		
1.0		
1.0		
1.0		
124.0	age k fecundity	fec(iage)
469.0	age k+1 fecundity	
975.0	age k+2 fecundity	
1616.0	age k+3 fecundity	
2739.0	age k+4 fecundity	
3463.0	age k+5 fecundity	
4129.0	age k+6 fecundity	
4888.0	age k+7 fecundity	
5613.0	age k+8 fecundity	
0.3296	Fishing mortalities (jy-ly+1 values)	f(t)
0.2322		
0.1901		
0.1541		

Appendix B-1 The format of the AGEERR.CMD input file (continued).

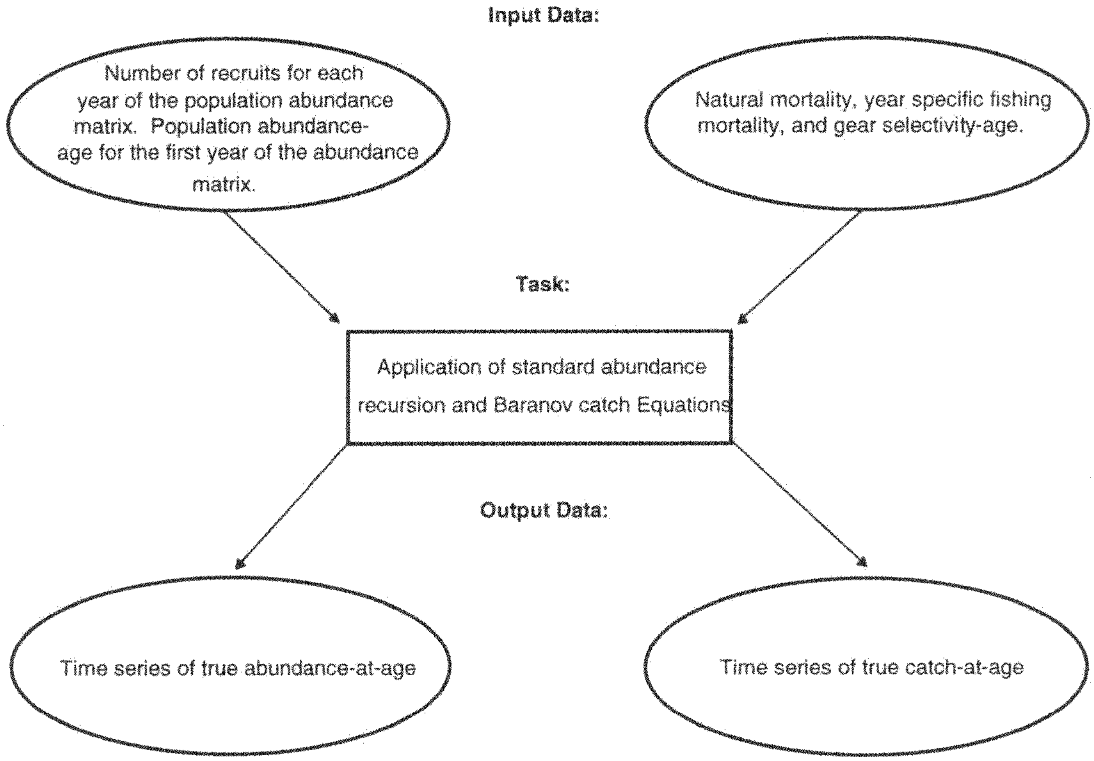
0.05901		
0.0813		
-1.0	end fishing	
100.0	Sample size	samsiz
0.816400	s.d. of observed age at age of recruitment	sigmar
1.282300	s.d. of observed age at age of last age	sigmaa
-0.2542	alpha parameter or zero	alpha
0.816400	constant s.d. of observed age	sigcon
-1.0	bias	bias
7	pooling age or zero	ipol
0.3	c.v. of survey data	cvsurv
0.05	c.v. of total catch	cvcat
6.0	Age at full maturity	fulmat
3	age of full selectivity	IFUL
4278.0	fecundity of plus group or zero	FECPLS

Appendix B-2 The format of the CAGEM.CMD input file.

Gulkana River Grayling 1986-1991	TITLE OF ANALYSIS
0.3000	NATURAL MORTALITY
0.0	END MORTALITIES
0	no fixing of variables
1	pooling of data at last age
100000.0	SURVEY LAMBDA (λ_s)

Appendix B-3 Overall structure of the generation of the true population.

Procedure 1



Appendix B-4 A sample AGEOUT.OUT file.

```
***************************************************************************
Initial abundances for year      1986
total is  95390.
 34253.  30311.  23874.  4540.  2331.   45.   25.    7.    4.

Catches for year      1986
total is  16724.
  1772.  7413.  5839.  1110.   570.   11.    6.    2.    1.
In year 1988:Recr. =   22390.
***************************************************************************
Initial abundances for year      1987
total is  97701.
 41271.  23858.  16150.  12720.  2419.  1242.   24.   13.    4.

Catches for year      1987
total is  11677.
  1517.  4296.  2908.  2290.   436.   224.    4.    2.    1.
In year 1989:Recr. =   46004.
***************************************************************************
Initial abundances for year      1988
total is  84805.
 22390.  29275.  14012.  9485.  7471.  1421.   729.   14.    8.

Catches for year      1988
total is  10056.
   676.  4399.  2106.  1425.  1123.   213.   110.    2.    1.
In year 1990:Recr. =   90218.
***************************************************************************
Initial abundances for year      1989
total is 100240.
 46004.  16008.  17933.  8583.  5810.  4576.   870.   447.    9.

Catches for year      1989
total is   7847.
  1130.  1983.  2221.  1063.   720.   567.   108.   55.    1.
In year 1991:Recr. =   16940.
***************************************************************************
Initial abundances for year      1990
total is 157766.
 90218.  33113.  10165.  11388.  5451.  3690.  2906.   553.   284.

Catches for year      1990
total is   4205.
   856.  1642.   504.   565.   270.   183.   144.   27.   14.
In year 1992:Recr. =       0.
***************************************************************************
Initial abundances for year      1991
total is 130017.
 16940.  66102.  23125.  7099.  7953.  3807.  2577.  2029.   386.

Catches for year      1991
total is   7864.
   221.  4468.  1563.   480.   538.   257.   174.   137.   26.
In year 1993:Recr. =       0.
NT =        6
===========================================================================
```

Appendix B-4 A sample AGEOUT.OUT file (continued).

Age	Year	Gear	ln(catch)	catch	abundance	ln(abund)	sel(age)
2	1986	1	7.4796	1772.	34253.	10.4415	.1870
3	1986	1	8.9111	7413.	30311.	10.3193	1.0000
4	1986	1	8.6723	5839.	23874.	10.0805	1.0000
5	1986	1	7.0125	1110.	4540.	8.4207	1.0000
6	1986	1	6.3458	570.	2331.	7.7541	1.0000
7	1986	1	2.3984	11.	45.	3.8067	1.0000
8	1986	1	1.8107	6.	25.	3.2189	1.0000
9	1986	1	.5377	2.	7.	1.9459	1.0000
10	1986	1	-.0219	1.	4.	1.3863	1.0000
2	1987	1	7.3243	1517.	41271.	10.6279	.1870
3	1987	1	8.3654	4296.	23858.	10.0799	1.0000
4	1987	1	7.9752	2908.	16150.	9.6897	1.0000
5	1987	1	7.7365	2290.	12720.	9.4509	1.0000
6	1987	1	6.0766	436.	2419.	7.7911	1.0000
7	1987	1	5.4100	224.	1242.	7.1245	1.0000
8	1987	1	1.4626	4.	24.	3.1771	1.0000
9	1987	1	.8748	2.	13.	2.5893	1.0000
10	1987	1	-.3982	1.	4.	1.3163	1.0000
2	1988	1	6.5164	676.	22390.	10.0164	.1870
3	1988	1	8.3892	4399.	29275.	10.2845	1.0000
4	1988	1	7.6524	2106.	14012.	9.5477	1.0000
5	1988	1	7.2622	1425.	9485.	9.1575	1.0000
6	1988	1	7.0235	1123.	7471.	8.9187	1.0000
7	1988	1	5.3636	213.	1421.	7.2589	1.0000
8	1988	1	4.6970	110.	729.	6.5923	1.0000
9	1988	1	.7496	2.	14.	2.6449	1.0000
10	1988	1	.1618	1.	8.	2.0571	1.0000
2	1989	1	7.0298	1130.	46004.	10.7365	.1870
3	1989	1	7.5922	1983.	16008.	9.6808	1.0000
4	1989	1	7.7058	2221.	17933.	9.7944	1.0000
5	1989	1	6.9690	1063.	8583.	9.0576	1.0000
6	1989	1	6.5787	720.	5810.	8.6674	1.0000
7	1989	1	6.3400	567.	4576.	8.4286	1.0000
8	1989	1	4.6802	108.	870.	6.7688	1.0000
9	1989	1	4.0135	55.	447.	6.1022	1.0000
10	1989	1	.0661	1.	9.	2.1548	1.0000
2	1990	1	6.7518	856.	90218.	11.4100	.1870
3	1990	1	7.4035	1642.	33113.	10.4077	1.0000
4	1990	1	6.2225	504.	10165.	9.2267	1.0000
5	1990	1	6.3361	565.	11388.	9.3403	1.0000
6	1990	1	5.5993	270.	5451.	8.6035	1.0000
7	1990	1	5.2091	183.	3690.	8.2133	1.0000
8	1990	1	4.9704	144.	2906.	7.9745	1.0000
9	1990	1	3.3105	27.	553.	6.3147	1.0000
10	1990	1	2.6439	14.	284.	5.6481	1.0000
2	1991	1	5.3977	221.	16940.	9.7374	.1870
3	1991	1	8.4047	4468.	66102.	11.0989	1.0000
4	1991	1	7.3544	1563.	23125.	10.0487	1.0000
5	1991	1	6.1735	480.	7099.	8.8677	1.0000
6	1991	1	6.2871	538.	7953.	8.9813	1.0000
7	1991	1	5.5503	257.	3807.	8.2445	1.0000
8	1991	1	5.1600	174.	2577.	7.8543	1.0000
9	1991	1	4.9213	137.	2029.	7.6155	1.0000
10	1991	1	3.2615	26.	386.	5.9557	1.0000

==

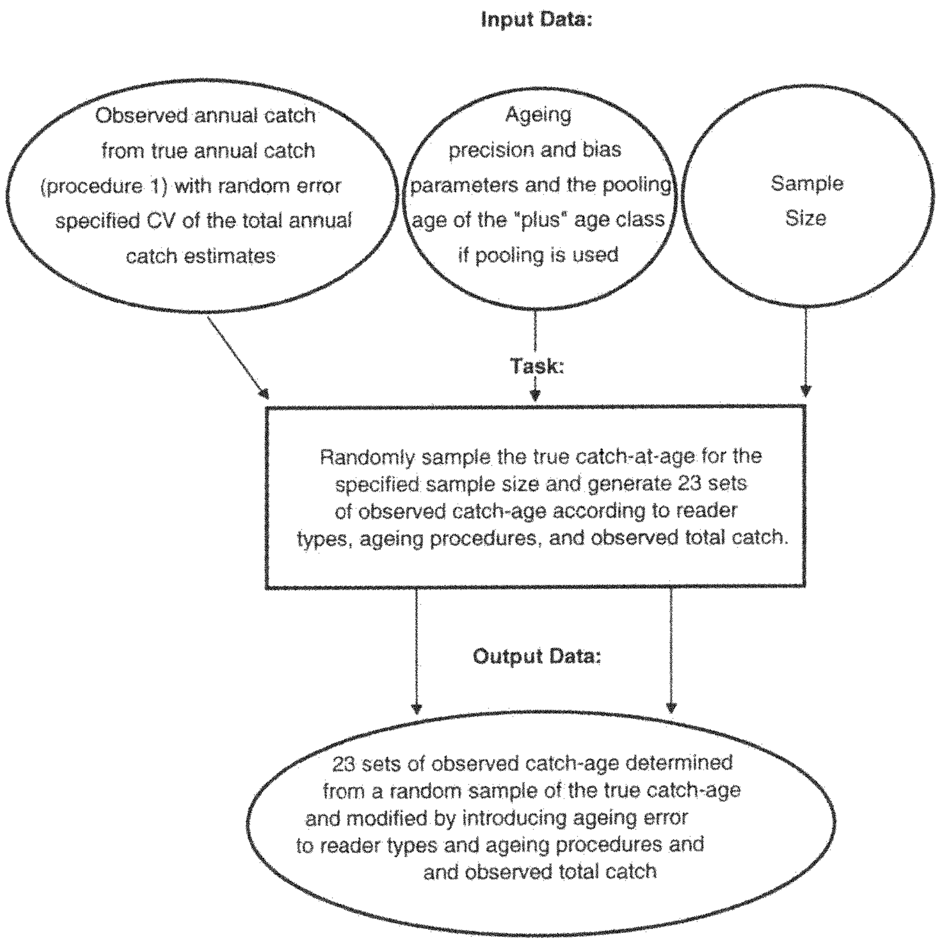
Appendix B-4 A sample AGEOUT.OUT file (continued).

Year	Gear	fish mort	catch	abundance
1986	1	.32960	16724	95390.
1987	1	.23220	11677	97701.
1988	1	.19010	10056	84805.
1989	1	.15410	7847	100240.
1990	1	.05901	4205	157766.
1991	1	.08130	7864	130017.

sample size is 100

Appendix B-5 Overall structure of the generation of the observed catch-at-age data.

Procedure 2

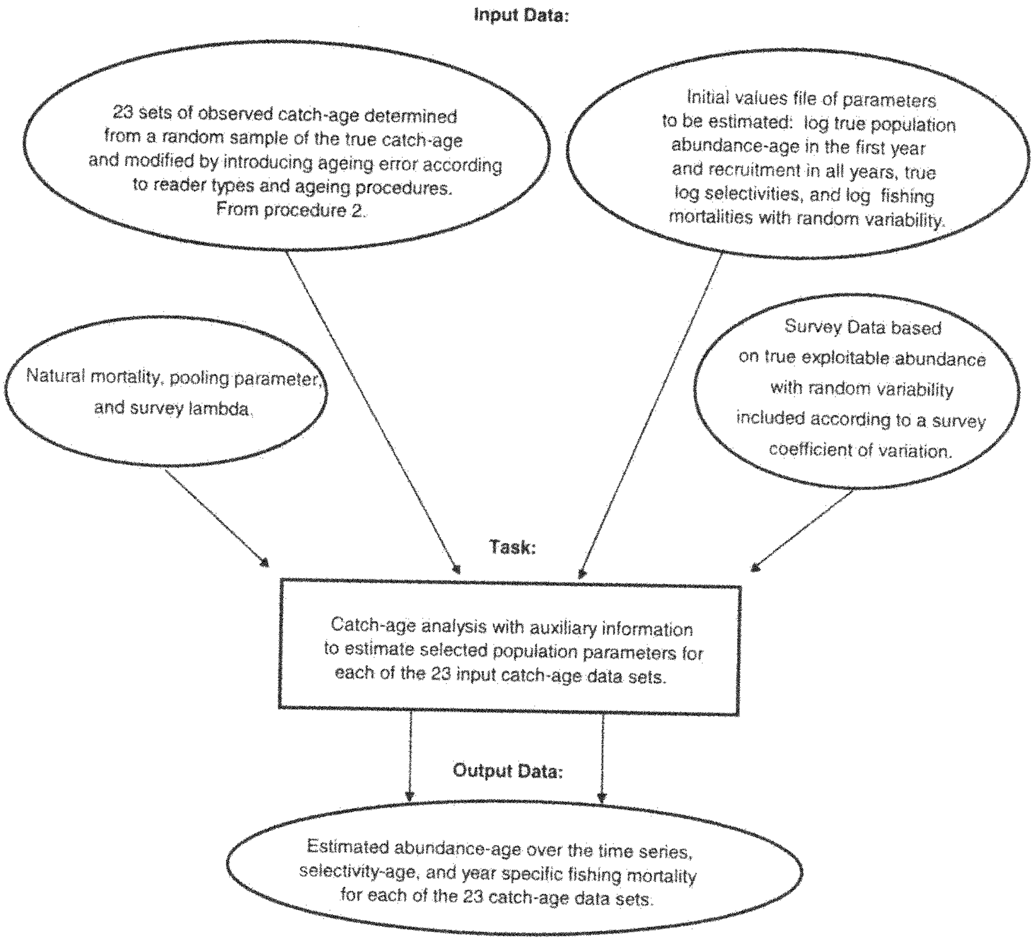


Appendix B-6 A sample SAMSIZE.OUT file.

rep#	R0	R1	R2	R3	R4	R1m1	R2m1	R3m1	R4m1	R1m2	R2m2	R3m2	R4m2	R1vR1	R2vR2	R3vR3	R4vR4	R2vR3	R3vR4	R1F1	R1F2	R4F1	R4F2
1	100	100	100	100	100	78	73	78	73	100	100	100	100	100	100	100	100	100	100	64	100	82	100
2	100	100	100	100	100	78	78	78	78	100	100	100	100	100	100	100	100	100	100	60	100	79	100
3	100	100	100	100	100	79	76	79	76	100	100	100	100	100	100	100	100	100	100	64	100	82	100
4	100	100	100	100	100	79	74	79	74	100	100	100	100	100	100	100	100	100	100	61	100	84	100
5	100	100	100	100	100	80	77	80	77	100	100	100	100	100	100	100	100	100	100	64	100	82	100
6	100	100	100	100	100	80	73	80	73	100	100	100	100	100	100	100	100	100	100	64	100	84	100
7	100	100	100	100	100	75	77	75	77	100	100	100	100	100	100	100	100	100	100	60	100	79	100
8	100	100	100	100	100	80	77	80	77	100	100	100	100	100	100	100	100	100	100	63	100	85	100
9	100	100	100	100	100	81	70	81	70	100	100	100	100	100	100	100	100	100	100	64	100	82	100
10	100	100	100	100	100	81	77	81	77	100	100	100	100	100	100	100	100	100	100	64	100	84	100
11	100	100	100	100	100	76	77	76	77	100	100	100	100	100	100	100	100	100	100	62	100	80	100
12	100	100	100	100	100	81	77	81	77	100	100	100	100	100	100	100	100	100	100	66	100	82	100
13	100	100	100	100	100	79	78	79	78	100	100	100	100	100	100	100	100	100	100	62	100	83	100
14	100	100	100	100	100	80	78	80	78	100	100	100	100	100	100	100	100	100	100	63	100	83	100
15	100	100	100	100	100	79	79	79	79	100	100	100	100	100	100	100	100	100	100	63	100	84	100
16	100	100	100	100	100	78	78	78	78	100	100	100	100	100	100	100	100	100	100	61	100	82	100
17	100	100	100	100	100	82	76	82	76	100	100	100	100	100	100	100	100	100	100	67	100	85	100
18	100	100	100	100	100	79	77	79	77	100	100	100	100	100	100	100	100	100	100	63	100	85	100
19	100	100	100	100	100	79	74	79	74	100	100	100	100	100	100	100	100	100	100	61	100	82	100
20	100	100	100	100	100	80	75	80	75	100	100	100	100	100	100	100	100	100	100	65	100	84	100
21	100	100	100	100	100	75	75	75	75	100	100	100	100	100	100	100	100	100	100	60	100	80	100
22	100	100	100	100	100	83	79	83	79	100	100	100	100	100	100	100	100	100	100	68	100	86	100
23	100	100	100	100	100	81	76	81	76	100	100	100	100	100	100	100	100	100	100	64	100	84	100
24	100	100	100	100	100	79	77	79	77	100	100	100	100	100	100	100	100	100	100	62	100	81	100
25	100	100	100	100	100	79	77	79	77	100	100	100	100	100	100	100	100	100	100	62	100	82	100
26	100	100	100	100	100	80	75	80	75	100	100	100	100	100	100	100	100	100	100	62	100	84	100
27	100	100	100	100	100	77	79	77	79	100	100	100	100	100	100	100	100	100	100	62	100	83	100
28	100	100	100	100	100	80	76	80	76	100	100	100	100	100	100	100	100	100	100	64	100	83	100
29	100	100	100	100	100	79	77	79	77	100	100	100	100	100	100	100	100	100	100	64	100	80	100
30	100	100	100	100	100	80	79	80	79	100	100	100	100	100	100	100	100	100	100	64	100	84	100

Appendix B-7 Overall structure of the catch-age analysis with auxiliary information.

Procedure 3



Appendix B-8 A sample INITS.DAT file.

Parameter value	Age	Year	Gear Group	Selectivity Group
4.39444972439[a]	7	1986		
7.75405235757[a]	6	1986		
8.42068235394[a]	5	1986		
10.0805454980[a]	4	1986		
10.3192619360[a]	3	1986		
10.4415295360[a]	2	1986		
10.6279129100[a]	2	1987		
10.0163692800[a]	2	1988		
10.7364812470[a]	2	1989		
11.4099882980[a]	2	1990		
9.73743206045[a]	2	1991		
-1.01213E-001[b]		1986	1	
-2.27145E-001[b]		1987	1	
-3.85707E-002[b]		1988	1	
-1.5929267548[b]		1989	1	
-1.54027E-001[b]		1990	1	
2.963485E-002[b]		1991	1	
-1.6762127550[c]	2		1	1

[a] Natural logarithm of abundance.
[b] Natural logarithm of fishing mortality.
[c] Natural logarithm of selectivity.

Appendix B-9 A sample SURVEY.DAT file.

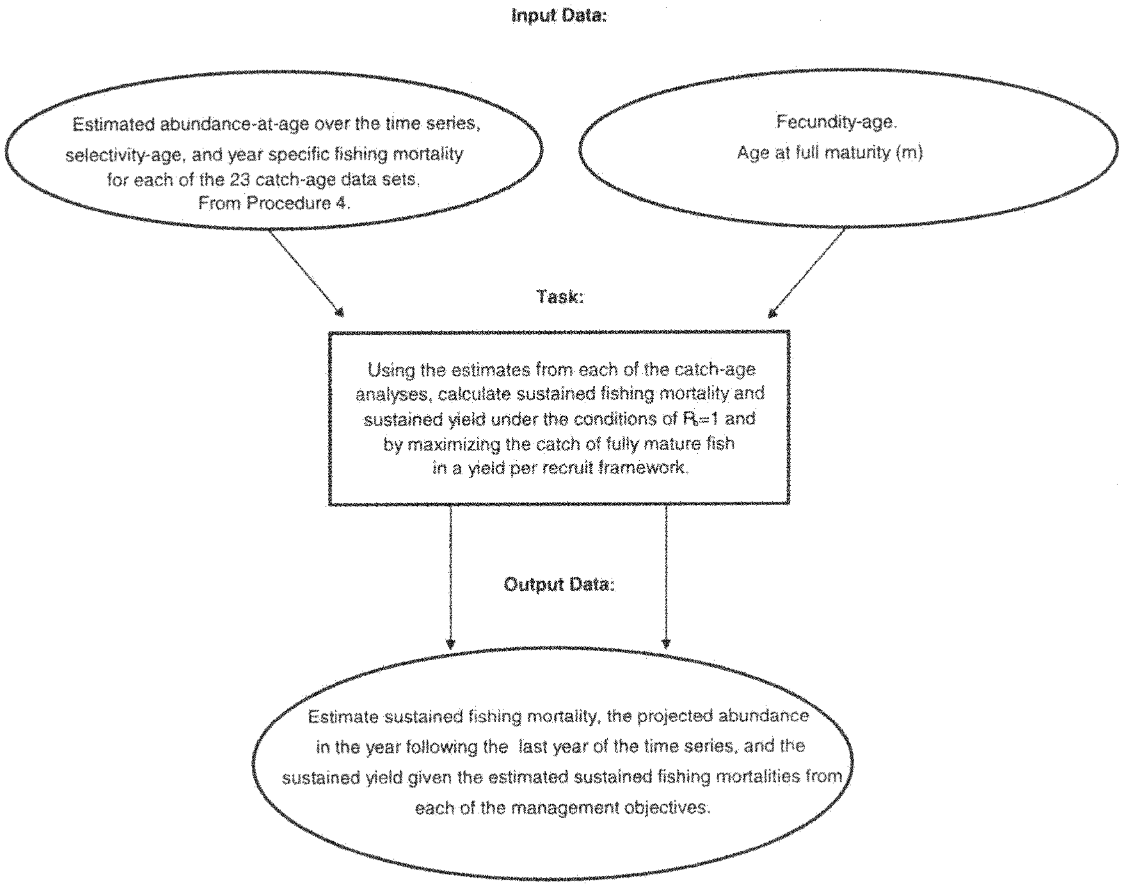
Year	Gear	Survey Abundance (in number of fish)
1986	1	61220.057798680410000
1987	1	40107.920474579790000
1988	1	89409.043477060710000
1989	1	110228.137462648100000
1990	1	28206.003962815520000
1991	1	118785.488725420900000

Appendix B-10 A sample CATCH.DAT file.

Age	Year	Gear	Catch (in number of fish)
2	1986	1	7076.000000000000000
2	1987	1	3029.000000000000000
2	1988	1	3849.000000000000000
2	1989	1	2341.000000000000000
2	1990	1	1461.000000000000000
2	1991	1	3170.000000000000000
3	1986	1	6545.000000000000000
3	1987	1	2596.000000000000000
3	1988	1	1722.000000000000000
3	1989	1	1534.000000000000000
3	1990	1	1211.000000000000000
3	1991	1	2570.000000000000000
4	1986	1	2830.000000000000000
4	1987	1	3137.000000000000000
4	1988	1	1823.000000000000000
4	1989	1	1695.000000000000000
4	1990	1	585.000000000000000
4	1991	1	1457.000000000000000
5	1986	1	885.000000000000000
5	1987	1	1623.000000000000000
5	1988	1	1823.000000000000000
5	1989	1	1130.000000000000000
5	1990	1	376.000000000000000
5	1991	1	514.000000000000000
6	1986	1	354.000000000000000
6	1987	1	108.000000000000000
6	1988	1	709.000000000000000
6	1989	1	484.000000000000000
6	1990	1	292.000000000000000
6	1991	1	171.000000000000000
7	1986	1	0.0000000000000000
7	1987	1	324.000000000000000
7	1988	1	203.000000000000000
7	1989	1	888.000000000000000
7	1990	1	251.000000000000000
7	1991	1	685.000000000000000

Appendix B-11 Overall structure of the generation of sustained yield estimates.

Procedure 4



Appendix B-12 Description of sustained yield output files.

Filename	SY	Scenario	Reader Type(s)	Description
sy1r0.out	SY_{ST}	1	R0	One Reader, Single reading
sy1r1.out	SY_{ST}	1	R1	One Reader, Single reading
sy1r2.out	SY_{ST}	1	R2	One Reader, Single reading
sy1r3.out	SY_{ST}	1	R3	One Reader, Single reading
sy1r4.out	SY_{ST}	1	R4	One Reader, Single reading
sy1r1m1.out	SY_{ST}	2a	R1	One Reader,Three readings, disregard non-modal ages
sy1r2m1.out	SY_{ST}	2a	R2	One Reader,Three readings, disregard non-modal ages
sy1r3m1.out	SY_{ST}	2a	R3	One Reader,Three readings, disregard non-modal ages
sy1r4m1.out	SY_{ST}	2a	R4	One Reader,Three readings, disregard non-modal ages
sy1r1m2.out	SY_{ST}	2b	R1	One Reader,Three readings, median of non-modal ages
sy1r2m2.out	SY_{ST}	2b	R2	One Reader,Three readings, median of non-modal ages
sy1r3m2.out	SY_{ST}	2b	R3	One Reader,Three readings, median of non-modal ages
sy1r4m2.out	SY_{ST}	2b	R4	One Reader,Three readings, median of non-modal ages
sy1r1vr1.out	SY_{ST}	3	R1, R1	One reading by two readers, rounded mean if disagreement
sy1r2vr2.out	SY_{ST}	3	R2, R2	One reading by two readers, expert reader's age if disagreement
sy1r3vr3.out	SY_{ST}	3	R3, R3	One reading by two readers, expert reader's age if disagreement
sy1r4vr4.out	SY_{ST}	3	R4, R4	One reading by two readers, expert reader's age if disagreement
sy1r2vr3.out	SY_{ST}	3	R2, R3	One reading by two readers, expert reader's age if disagreement
sy1r3vr4.out	SY_{ST}	3	R3, R4	One reading by two readers, expert reader's age if disagreement
sy1r1f1.out	SY_{ST}	4a	R1, R1	Three readings by two readers, disregard non-modal ages
sy1r4f2.out	SY_{ST}	4a	R4, R4	Three readings by two readers, disregard non-modal ages
sy1r1f2.out	SY_{ST}	4b	R1, R1	Three readings by two readers, median of non-modal ages
sy1r4f2.out	SY_{ST}	4b	R4, R4	Three readings by two readers, median of non-modal ages
sy2r0.out	SY_{m+}	1	R0	One Reader, Single reading
sy2r1.out	SY_{m+}	1	R1	One Reader, Single reading
sy2r2.out	SY_{m+}	1	R2	One Reader, Single reading
sy2r3.out	SY_{m+}	1	R3	One Reader, Single reading
sy2r4.out	SY_{m+}	1	R4	One Reader, Single reading
sy2r1m1.out	SY_{m+}	2a	R1	One Reader,Three readings, disregard non-modal ages
sy2r2m1.out	SY_{m+}	2a	R2	One Reader,Three readings, disregard non-modal ages
sy2r3m1.out	SY_{m+}	2a	R3	One Reader,Three readings, disregard non-modal ages
sy2r4m1.out	SY_{m+}	2a	R4	One Reader,Three readings, disregard non-modal ages
sy2r1m2.out	SY_{m+}	2b	R1	One Reader,Three readings, median of non-modal ages
sy2r2m2.out	SY_{m+}	2b	R2	One Reader,Three readings, median of non-modal ages
sy2r3m2.out	SY_{m+}	2b	R3	One Reader,Three readings, median of non-modal ages
sy2r4m2.out	SY_{m+}	2b	R4	One Reader,Three readings, median of non-modal ages
sy2r1vr1.out	SY_{m+}	3	R1, R1	One reading by two readers, rounded mean if disagreement
sy2r2vr2.out	SY_{m+}	3	R2, R2	One reading by two readers, expert reader's age if disagreement
sy2r3vr3.out	SY_{m+}	3	R3, R3	One reading by two readers, expert reader's age if disagreement
sy2r4vr4.out	SY_{m+}	3	R4, R4	One reading by two readers, expert reader's age if disagreement
sy2r2vr3.out	SY_{m+}	3	R2, R3	One reading by two readers, expert reader's age if disagreement
sy2r3vr4.out	SY_{m+}	3	R3, R4	One reading by two readers, expert reader's age if disagreement
sy2r1f1.out	SY_{m+}	4a	R1, R1	Three readings by two readers, disregard non-modal ages
sy2r4f2.out	SY_{m+}	4a	R4, R4	Three readings by two readers, disregard non-modal ages
sy2r1f2.out	SY_{m+}	4b	R1, R1	Three readings by two readers, median of non-modal ages
sy2r4f2.out	SY_{m+}	4b	R4, R4	Three readings by two readers, median of non-modal ages

Appendix B-13 A sample SY1*.OUT output file.

[a] rep#	[b] FST	[c] Proj. abu.	[d] SYST	[e] Fmort1st	[f] Fmortlast	[g] Abun1st	[h] Abunlast	[i] Selectivities					
1	0.3769	176274	32707	0.2967	0.0739	106326	148126	0.200	1	1	1	1	1
2	0.3982	136373	26490	0.3404	0.0972	85535	118112	0.190	1	1	1	1	1
3	0.3562	158794	28583	0.2902	0.0749	100936	137075	0.200	1	1	1	1	1
4	0.4260	185467	38199	0.2901	0.0636	100196	155117	0.190	1	1	1	1	1
5	0.3509	127061	22074	0.3417	0.0891	91809	108644	0.190	1	1	1	1	1
6	0.3393	100157	17426	0.3820	0.1195	84964	91635	0.190	1	1	1	1	1
7	0.4116	156578	30993	0.3353	0.0788	92411	131937	0.190	1	1	1	1	1
8	0.4065	125789	24773	0.3961	0.0933	83566	109760	0.170	1	1	1	1	1
9	0.3962	173628	33902	0.2864	0.0772	103255	148345	0.190	1	1	1	1	1
10	0.4366	175197	36732	0.3086	0.0747	95839	146345	0.200	1	1	1	1	1
11	0.4398	154038	31658	0.3357	0.0803	89413	129316	0.170	1	1	1	1	1
12	0.4030	186100	36777	0.2721	0.0703	100798	156998	0.200	1	1	1	1	1
13	0.3677	148836	27260	0.3097	0.0812	98910	124713	0.220	1	1	1	1	1
14	0.3484	134921	23582	0.3165	0.0895	97178	119562	0.170	1	1	1	1	1
15	0.4647	165823	35800	0.3652	0.0881	93176	141473	0.160	1	1	1	1	1
16	0.3403	114805	19790	0.3600	0.1120	89118	100998	0.210	1	1	1	1	1
17	0.4849	190524	43158	0.3142	0.0770	94736	158991	0.190	1	1	1	1	1
18	0.4330	167375	34306	0.3334	0.0756	92863	141379	0.170	1	1	1	1	1
19	0.3337	106299	17871	0.3375	0.1051	85279	95084	0.170	1	1	1	1	1
20	0.3941	136209	26855	0.3516	0.0922	89399	119708	0.200	1	1	1	1	1
21	0.3950	127784	24839	0.3664	0.0982	86186	111628	0.190	1	1	1	1	1
22	0.3187	126983	21124	0.3107	0.0934	98169	112010	0.220	1	1	1	1	1
23	0.4289	153647	30921	0.3220	0.0788	88091	126994	0.180	1	1	1	1	1
24	0.4772	200312	45827	0.2765	0.0606	102850	168893	0.200	1	1	1	1	1
25	0.3285	107454	17857	0.3804	0.1215	89513	95964	0.190	1	1	1	1	1

[a] Program replication number.
[b] Sustained fishing mortality given the equilibrium management strategy.
[c] Projected absolute abundance in the year following the last year of the analysis.
[d] Sustained yield in the year following the last year of the analysis.
[e] Fishing mortality in the first year of the analysis.
[f] Fishing mortality in the last year of the analysis.
[g] Absolute abundance in the first year of the analysis.
[h] Absolute abundance in the last year of the analysis.
[i] Selectivity-at-age, only first age is estimated.

Appendix B-14 A sample SY2*.OUT output file.

rep# [a]	Fm+ [b]	SYm+ [c]
1	0.204	18358
2	0.205	13443
3	0.204	16902
4	0.205	18741
5	0.204	14787
6	0.203	10087
7	0.203	15544
8	0.204	13069
9	0.203	17509
10	0.202	15810
11	0.207	15998
12	0.205	16608
13	0.204	15212
14	0.203	13451
15	0.205	15572
16	0.202	10696
17	0.204	18884
18	0.205	15127
19	0.203	9669
20	0.204	12723
21	0.205	12698
22	0.200	11674
23	0.203	13970
24	0.203	17972
25	0.204	10905

[a] Program replication number.
[b] Sustained fishing mortality given the maximize catch of fully mature fish management strategy.
[c] Sustained yield in the year following the last year of the analysis.

Appendix B-15 Estimated population parameters of the mainstem Gulkana River grayling stock either contained in, or estimated from, Bosch (1995).

Natural Mortality **0.3**

Year	Fishing Mortality
1986	**0.32960**
1987	**0.23220**
1988	**0.19010**
1989	**0.15410**
1990	**0.05901**
1991	**0.08130**

Abundance

	AGE									
Year	2	3	4	5	6	7+	7	8	9	10
1986	**34253**	**30311**	**23874**	**4540**	**2331**	81	**36**	**22**	**14**	**9**
1987	**41271**	23852	16127	12702	2416	1283				
1988	**22390**	29274	14007	9471	7459	2172				
1989	**46004**	16010	17946	8587	5806	5905				
1990	**90218**	33117	10175	11405	5457	7443				
1991	**16940**	66100	23125	7105	7964	9008				

	AGE					
	2	3	4	5	6	7+
Selectivity	**0.187**	**1**	**1**	**1**	**1**	**1**

	AGE									
	2	3	4	5	6	7+	7	8	9	10
net fecundity	**124**	**469**	**975**	**1616**	**2739**	**4140**	**3463**	**4192**	**4888**	**5613**

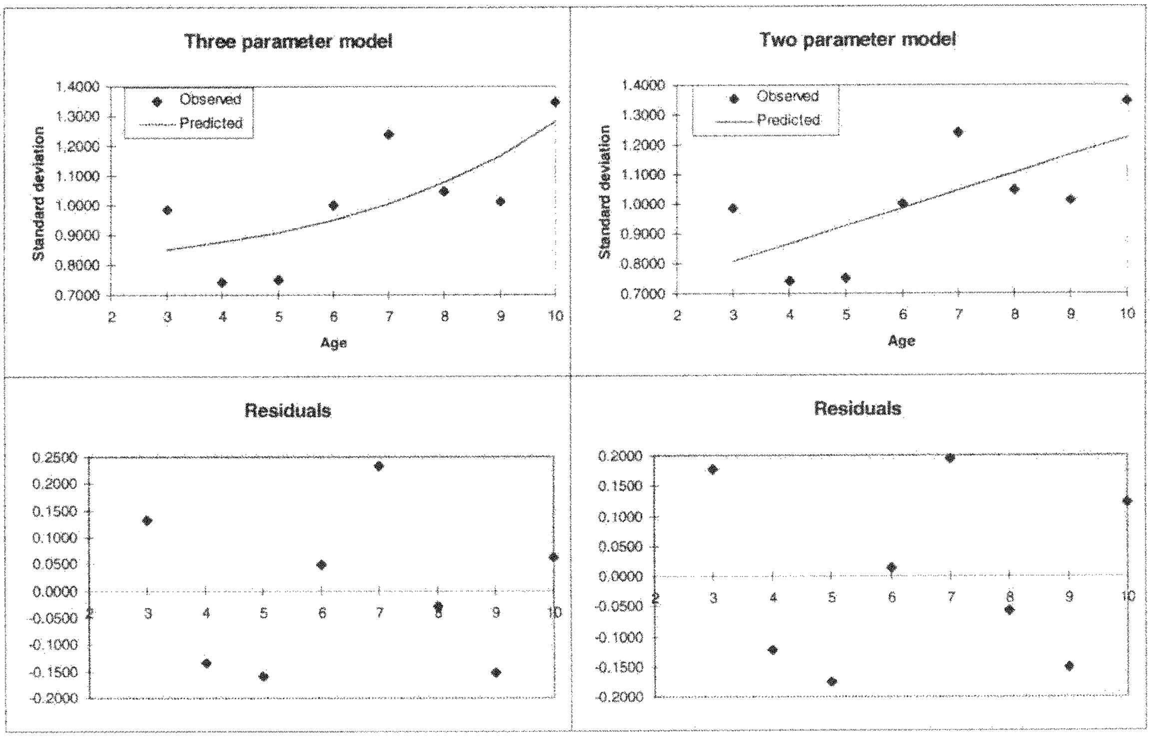
Bolded parameters are required by program AGEERR.

Appendix B-16 Estimated standard deviation of observed given true (expected) age by true (expected) age class.

Age	Standard Deviation
3	0.984
4	0.743
5	0.751
6	0.856
7	1.134
8	1.046
9	1.013
10	1.344

Appendix B-17 Curve fitting of standard deviation of observed given true (expected) age as a function of age.

Three parameter model (α not equal 0)					Two parameter model ($\alpha = 0$)		
A	σ_r	σ_A	α		A	σ_r	σ_A
10	0.8164	1.2823	-0.2542		10	0.6875	1.2230
		alpha not 0			alpha =0		
AGE	Observed	Predicted	resids	(O-E)^2	Predicted	resids	(O-E)^2
3	0.9835	0.8512	0.1323	0.0175	0.8065	0.1770	0.0313
4	0.7435	0.8766	-0.1331	0.0177	0.8660	-0.1225	0.0150
5	0.7505	0.9092	-0.1587	0.0252	0.9255	-0.1750	0.0306
6	0.9991	0.9513	0.0478	0.0023	0.9850	0.0141	0.0002
7	1.2378	1.0056	0.2322	0.0539	1.0445	0.1933	0.0374
8	1.0464	1.0756	-0.0293	0.0009	1.1040	-0.0576	0.0033
9	1.0128	1.1659	-0.1531	0.0234	1.1635	-0.1507	0.0227
10	1.3443	1.2823	0.0619	0.0038	1.2230	0.1213	0.0147
			SSQ	0.1447		SSQ	0.1553



Appendix B-18 An AGEERR.CMD input data file based on the mainstem Gulkana River Grayling example.

1000	replications	reps
1986	starting year	ly
1991	ending year	jy
0.3	natural mortality	m
2	Recruitment age	k
10	Last age	la
34253.0	age k abundance in year 1	abun(iage,1)
30311.0	age k+1 abundance in year 1	abun(iage,1)
23874.0	age k+2 abundance in year 1	abun(iage,1)
4540.0	age k+3 abundance in year 1	abun(iage,1)
2331.0	age k+4 abundance in year 1	abun(iage,1)
36.0	age k+5 abundance in year 1	abun(iage,1)
22.0	age k+6 abundance in year 1	abun(iage,1)
14.0	age k+7 abundance in year 1	abun(iage,1)
9.0	age la abundance in year 1	abun(iage,1)
41271.0	age k abundance in year 2	abun(k,2)
22390.0	age k abundance in year 3	abun(k,3)
46004.0	age k abundance in year 4	abun(k,4)
90218.0	age k abundance in year 5	abun(k,5)
16940.0	age k abundance in year ly-jy+1	abun(k,jy-ly+1)
0.187	Selectivity (la-k+1 values)	sel(a)
1.0		
1.0		
1.0		
1.0		
1.0		
1.0		
1.0		
1.0		
124.0	age k fecundity	fec(iage)
469.0	age k+1 fecundity	
975.0	age k+2 fecundity	
1616.0	age k+3 fecundity	
2739.0	age k+4 fecundity	
3463.0	age k+5 fecundity	
4129.0	age k+6 fecundity	
4888.0	age k+7 fecundity	

Appendix B-18 An AGEERR.CMD input data file based on the mainstem Gulkana River Grayling example (continued).

5613.0	age k+8 fecundity	
0.32960	Fishing mortalities(jy-ly+1 values)	f(t)
0.23220		
0.19010		
0.15410		
0.05901		
0.08130		
-1.0	end fishing	
100.0	Sample size	samsiz
0.408200	s.d. of observed age at age of recruitment	sigmar
0.641200	s.d. of observed age at age of last age	sigmaa
-0.25420	alpha parameter or zero	alpha
0.408200	constant s.d. of observed age	sigcon
-1.0	bias	bias
7	POOLING AGE OR 0	ipol
0.22	c.v. of survey data	cvsurv
0.05	c.v. of total catch	cvcat
6.0	Age at full maturity	fulmat
3	AGE OF FULL SELECTIVITY	IFUL
4140	FECUNDITY OF PLUS GROUP OR 0	FECPLS

Appendix B-19 A CAGEM.CMD input data file based on the mainstem Gulkana River Grayling example.

Gulkana River Grayling 1986-1991	TITLE OF ANALYSIS
0.3000	NATURAL MORTALITY
0.0	END MORTALITIES
0	no fixing of variables
1	pooling of data at last age
1300.0	SURVEY LAMBDA (λ_s)

APPENDIX C FORMULAE RELATED TO PROGRAM AGEERR USERS MANUAL

Appendix C-1 Formulae used in the implementation of procedure 1 in Program AGEERR.

$$N_{a+1,t+1} = N_{a,t} e^{-Z_{a,t}} \tag{1}$$

$$N_{A+,t+1} = N_{(A+)-1,t} e^{-Z_{(A+)-1,t}} + N_{A+,t} e^{-Z_{A+,t}} \tag{2}$$

$$C_{a,t} = \mu_{a,t} N_{a,t} \tag{3}$$

$$\mu_{a,t} = \frac{F_{a,t}}{Z_{a,t}}\left[1 - e^{-Z_{a,t}}\right] \tag{4}$$

$$Z_{a,t} = F_{a,t} + M \tag{5}$$

$$F_{a,t} = s_a f_t \quad , \tag{6}$$

where $N_{a,t}$ is the true abundance of age a fish in year t, $Z_{a,t}$ is the total instantaneous fishing mortality, A+ is an aggregate plus age group, $C_{a,t}$ is the true catch, $\mu_{a,t}$ is the true exploitation rate, M is the true natural mortality rate, $F_{a,t}$ is the true fishing mortality rate, s_a is the true gear selectivity coefficient, and f_t is the true full recruitment fishing mortality (Deriso et al. 1985, 1989).

Appendix C-2 Descriptions of readers and ageing scenarios used in Program AGEERR.

Statistical characterizations of reader types:

R0 $a = b$
R1 a ~ $N(b, \sigma^2)$
R2 a ~ $N(b, \sigma(b)^2)$
R3 a ~ $N(b+c, \sigma^2)$
R4 a ~ $N(b+c, \sigma(b)^2)$
$\sigma(b) \geq \sigma$.

Let a be the observed age, b be the true age, c be the bias (positive or negative), σ^2 be constant standard, and $\sigma(b)^2$ be standard deviation as a function of true age.

Description of ageing scenarios:

scenario 1 Final observed age a is the result of a single reader ageing a structure of true age b a single time.

scenario 2a A single reader ages a structure of true age b three times resulting in three intermediate observed ages a_1, a_2, and a_3. Final observed age is the mode of the intermediate ages. If no modal age the structure is omitted from the sample.

scenario 2b Same as scenario 2a except if no modal age the final observed age is the median of the intermediate observed ages.

scenario 3 Two readers each age a structure of true age b a single time resulting in intermediate observed ages a_1 and a_2. Final observed age if $a_1 = a_2$ is a_1. If $a_1 \neq a_2$, then the structure is re-aged by an "expert" reader (R1) and final observed age is the age determined by the "expert". If two R1 type readers are used, final observed age in disagreements is the rounded mean of the two ages.

scenario 4a Scenario 4b is a combination of scenarios 2a and 3. Two readers each read a structure of true age b three times resulting in intermediate observed ages a_1, a_2, and a_3 (from reader 1) and a_4, a_5, and a_6 (from reader 2). If the intermediate ages of either reader is non-modal, then the structure is omitted from the sample. If mode(a_1, a_2, a_3) = mode(a_4, a_5, a_6), then final observed age is mode(a_1, a_2, a_3). If mode(a_1, a_2, a_3) $\neq$ mode(a_4, a_5, a_6) then the age determined by the "expert" reader (R1) is the final observed age.

scenario 4b Same as scenario 4a except if the intermediate ages of reader 1 or reader 2 are non-modal, then the median is used in subsequent comparisons.

Appendix C-3 Formulae used in the implementation of procedure 2 in Program AGEERR.

Classification Matrix Formulation:

$$\Phi = (\sigma_r, \sigma_A, \alpha) \tag{7}$$

$$\sigma(b) = \begin{cases} \sigma_r + (\sigma_A - \sigma_r)\dfrac{1 - e^{-\alpha(b-r)}}{1 - e^{-\alpha(A-r)}}; & \alpha \neq 0 \\ \sigma_r + (\sigma_A - \sigma_r)\dfrac{b - r}{A - r}; & \alpha = 0 \end{cases} \tag{8}$$

$$\chi_{ab}(\Phi) = \frac{1}{\sqrt{2\pi}\,\sigma(b)} e^{-\frac{1}{2}\left[\frac{a-b}{\sigma(b)}\right]^2} \tag{9}$$

$$q(a|b,\Phi) = \frac{\chi_{ab}(\Phi)}{\sum_{a=r}^{A} \chi_{ab}(\Phi)} \tag{10}$$

$$\mathbf{Q}(\Phi) = \left[q(a|b,\Phi)\right]_{a=r,r+1,\ldots,A} \quad . \tag{11}$$

The preceding five equations define the classification matrix [$\mathbf{Q}(\Phi)$]. The elements of the classification matrix are the probabilities that a fish of true age b is assigned an observed age a. Equation 10 describes that Φ (the parameter vector of the classification matrix) is made up of σ_r and σ_A (the lower and upper bounds of $\sigma(b)$ corresponding to the standard deviation at the recruitment and oldest ages), and a parameter α that governs the non-linearity of σ(b). Equation 11 describes $\sigma(b)$ (the standard deviation of observed age a given true age b) as a function of σ_r, σ_A, α, and A (the oldest true age in the data base). The chi matrix [$\chi_{ab}(\Phi)$], defined by the density function in equation 12, has columns vectors corresponding to a discrete normal probability function of observed age a given true age b. The elements of the classification matrix [q($a|b$,Φ)] are weighted in equation 13 such that the sum of each column vector of the classification matrix is equal to one. Finally, equation 14 explicitly defines q($a|b$,Φ) as the elements of the classification matrix $\mathbf{Q}(\Phi)$.

Appendix C-3 Formulae used in the implementation of procedure 2 in Program AGEERR (continued).

Observed catch-at-age:

$$C'_{a,t} = C'_t \, \theta'_{a,t} \tag{12}$$

$$C'_t \sim N\left(C_t, \sigma_{C(t)}{}^2\right) \tag{13}$$

$$\sigma_{C(t)}{}^2 = \left(cv_C C_t\right)^2 \quad , \tag{14}$$

where $C'_{a,t}$ is the observed catch of age a fish during year t, C'_t is the observed total catch, $\theta'_{a,t}$ is the observed catch-age composition, C_t is the true total catch in year t, $\sigma_{C(t)}{}^2$ is the variance of the observed total catch, and cv_C is the constant coefficient of variation of the observed catch.

Appendix C-4 Formulae used in the implementation of procedure 3 in Program AGEERR.

The objective formula for parameter estimation is given as:

$$\min\left\{\sum_{a,t}\frac{\left[C'_{a,t}-\hat{C}_{a,t}\right]^2}{\hat{C}_{a,t}}+\lambda_s\left[\ln(SUR_t)-\ln\left(\hat{EN}_t\right)\right]^2\right\} \qquad (15)$$

$$\hat{EN}_t=\sum_a \hat{N}_{a,t}\hat{s}_a \quad , \qquad (16)$$

where $C'_{a,t}$ is the observed catch of age a fish in year t, $\hat{C}_{a,t}$ is the estimated catch, SUR_t is the total exploitable abundance from an independent survey, $\hat{EN}_t$ is the estimated total exploitable abundance, λ_s is a weighting factor for the auxiliary information, $\hat{N}_{a,t}$ is the estimated abundance, and $\hat{s}_a$ is the estimated selectivity-at-age. The catch $\hat{C}_{a,t}$, abundance $\hat{N}_{a,t}$, and selectivity $\hat{s}_a$ were estimated within program CAGEM using equations (1) - (6) and modifying each of the variables to include a hat (^) signifying that it is an estimated parameter.

Program AGEERR computes the survey exploitable abundance as:

$$\mathrm{SUR}_t \sim N\left(EN_t,\ \sigma_{S(t)}^{\ 2}\right) \qquad (17)$$

$$\sigma_{S(t)}^{\ 2} = \left(cv_S\ (EN_t)\right)^2 \quad , \qquad (18)$$

where EN_t is the true exploitable abundance in year t, $\sigma_{S(t)}^{\ 2}$ is the variance of the survey total exploitable abundance around the true exploitable abundance, and cv_S is the assumed constant coefficient of variation of the survey total exploitable abundance.

Appendix C-5 Formulae used to estimate F_{ST} and SY_{ST} in the implementation of procedure 4 in Program AGEERR.

The estimated number of eggs produced by the population each year is given as:

$$\hat{N}_{0,t} = \sum_{a=r}^{A} \hat{N}_{a,t} fec_a \quad , \tag{19}$$

where $\hat{N}_{0,t}$ is the estimated number of eggs produced in year t and fec_a is the net fecundity of an age a fish.

Early life survival is given as:

$$l_{r,t} = \hat{N}_{r,t+r} / \hat{N}_{0,t} \tag{20}$$

$$\bar{l}_r = \sum_{t=1}^{n} l_{r,t} \Big/ n \quad , \tag{21}$$

where $\bar{l}_r$ is the average early life survival, $l_{r,t}$ is the early life survival from brood year t, and $\hat{N}_{r,t+r}$ is the estimated abundance of recruitment age fish in year $t+r$.

The net reproductive value R_0 is given as:

$$l_a = \bar{l}_r \prod_{x=1}^{a-1} S_x \tag{22}$$

$$S_x = \exp(-Z_x) \text{ , for x > r} \tag{23}$$

$$R_0 = \sum_{a=r}^{A} fec_a l_a \quad , \tag{24}$$

where l_a is the survival from an egg to age a, S_x is the survival fraction-at-age, and R_0 is net reproductive value of an r year old fish.

Appendix C-5 Formulae used to estimate F_{ST} and SY_{ST} in the implementation of procedure 4 in Program AGEERR (continued).

The estimated catch (SY_{ST}) in the year following the last year of the analysis is given as:

$$SY_{ST} = \sum_{a} \hat{\mu}_a \hat{N}_{a,t+1} \tag{25}$$

$$\hat{\mu}_a = \frac{F_{ST}\hat{s}_a}{F_{ST}\hat{s}_a + M}\left[1 - \exp\left(-F_{ST}\hat{s}_a - M\right)\right] \tag{26}$$

$$\hat{N}_{a,t+1} = \begin{cases} \hat{N}_{0,t+1-r}\bar{l}_r \text{ , if } a = r \\ \hat{N}_{a-1,t} e^{-\hat{Z}_{a-1,t}} \text{ , if } r < a < A+ \\ \hat{N}_{(A+)-1,t} e^{-\hat{Z}_{(A+)-1,t}} + \hat{N}_{A+,t} e^{-\hat{Z}_{A+,t}} \text{ , if } a = A+ \end{cases} , \tag{27}$$

where F_{ST} is the fishing mortality such that $R_0 = 1$

Appendix C-6 Formulae used to estimate F_{m+} and SY_{m+} in the implementation of procedure 4 in Program AGEERR.

Catch-per-recruit for age m and older is given as:

$$C_{m+}/N_r = \sum_{a=m}^{A} \hat{\mu}_a \hat{L}_a \tag{28}$$

$$\hat{L}_a = \prod_{x=r}^{a-1} \hat{S}_x \quad , \tag{29}$$

where C_{m+}/N_r catch-per-recruit, and A is the oldest age recruited to the fishery, $\hat{L}_a$ is the survival from age r to age a, and $\hat{\mu}_a$ is the exploitation rate given F_{m+} calculated from equation (26) with F_{m+} in place of F_{ST}.

The estimated catch (SY_{m+}) in the year following the last year of the analysis is given by equations (25) - (27) with F_{m+} in place of F_{ST} where F_{m+} is the fishing mortality that that maximizes catch-per-recruit.

APPENDIX D PROCEDURES TO CONDUCT HYPOTHESIS TESTING

Hypothesis testing to determine if the estimated parameter value differed from the true parameter value by more 10% were conducted on the estimates of SY_{ST}, SY_{m+}, F_{ST}, F_{m+}, projected abundance, selectivity of age 2 fish, first year abundance, last year abundance, first year fishing mortality, and last year fishing mortality for each combination of reader type, ageing scenario, and sample size. To conduct the tests the following formulae are defined (Dr. Terrance J. Quinn, II, pers. comm.):

$$\hat{\theta} = \frac{\sum_{r=1}^{n} \theta_r}{n} \tag{1}$$

$$se(\hat{\theta}) = \sqrt{\frac{1}{n-1} \sum_{r=1}^{n} (\theta_r - \hat{\theta})^2} \tag{2}$$

$$RE = \frac{(\hat{\theta} - \theta)}{\theta} \tag{3}$$

$$se(RE) = \frac{se(\hat{\theta})}{\theta} \quad , \tag{4}$$

where θ_r is the parameter estimate from replication r, $\hat{\theta}$ is the Monte Carlo parameter estimate over n Monte Carlo replicates, $se(\hat{\theta})$ is the standard error of the parameter estimate, RE is the relative error of the parameter estimate, θ is the true value of the parameter, and $se(RE)$ is the standard error of the relative error. The null and alternate hypotheses are:

H_0: The relative error between the estimated and true parameter is less than 10%, $|E(RE)| < 0.10$;

H_a: The relative error between the estimated and true parameter is greater than or equal to 10%, $|E(RE)| \geq 0.10$.

A modified t-test was used to test the null hypothesis with the t statistic given by:

$$t = \begin{cases} 0, & \text{if } |RE| \leq 0.10 \\ \dfrac{(|RE| - 0.10)}{se(RE)}, & \text{if } |RE| > 0.10 \end{cases} \tag{5}$$

This is a two tailed test and the significance level was set at α=0.05. Although the significance level should be adjusted in a multiple t-test setting according to the Bonferroni inequality, this was not done because the number of tests conducted in this study would render the significance level unacceptably small, and hence the probability of making a type II error unacceptably large. It is accepted that the probability of making a type I error is increased by not making the adjustment, but it seems the lesser of two evils.

APPENDIX E SUMMARY OF PARAMETER ESTIMATES AMONG MONTE CARLO SIMULATIONS

Appendix E-1 Average and coefficient of variation (CV) of SY_{ST} across 1000 replicates by reader type(s)/scenarios (sample size = 100).

Age Sample Size = 100
Estimated value of SY_{ST} among reader(s)/scenarios.
True value of SY_{ST} is 29,867

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	29,875	29,789	29,904	29,689	29,717	29,200	29,414	29,818
R1	28,012	28,221	28,416	27,885	19,550	19,210	19,230	19,482
R2	28,048	28,368	28,230	27,803	18,991	18,480	19,055	18,971
R3	39,068	40,113	2,009	926	35,341	36,304	166	2
R4	38,648	38,604	1,604	400	34,100	34,385	156	1
R1M1	29,518	29,507	29,408	29,186	24,759	24,678	24,462	25,099
R2M1	30,572	30,425	30,731	30,359	27,344	26,780	27,339	27,470
R3M1	39,425	40,768	5,016	5,119	36,829	36,260	1,200	149
R4M1	40,703	40,858	4,822	4,049	38,677	36,176	1,900	324
R1M2	29,495	29,530	29,494	29,241	26,162	26,098	25,880	26,278
R2M2	29,302	29,155	29,461	29,088	26,001	25,310	25,763	25,802
R3M2	39,500	40,853	5,008	5,103	38,876	38,455	433	11
R4M2	39,450	40,254	4,406	4,155	38,274	37,380	396	12
R1VR1	24,323	24,482	24,308	24,085	17,093	16,853	16,891	16,929
R2VR2	28,667	29,166	29,167	28,876	20,866	20,428	20,695	20,928
R3VR3	30,333	20,758	3,776	43	13,013	3,380	9,441	193
R4VR4	27,541	14,223	5,366	13	14,473	4,759	10,800	472
R2VR3	34,103	27,423	23,161	27,492	24,877	17,044	14,513	13,877
R3VR4	27,798	16,330	4,528	36	12,603	3,106	9,687	338
R1F1	28,971	28,917	28,971	28,814	21,540	21,463	21,581	21,715
R1F2	29,032	28,961	29,019	28,871	18,921	18,825	18,827	18,884
R4F1	33,992	135,545	3,383	775	26,298	31,776	17,315	2,115
R4F2	36,688	162,755	3,336	2,308	28,307	41,320	8,225	2

Estimated value of the CV of SY_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	37%	37%	35%	36%	34%	36%	36%	36%
R1	35%	35%	34%	33%	36%	36%	37%	37%
R2	35%	34%	33%	33%	37%	35%	37%	37%
R3	28%	26%	323%	1108%	28%	28%	318%	2301%
R4	28%	26%	205%	1182%	28%	28%	299%	2130%
R1M1	37%	36%	34%	35%	35%	37%	39%	38%
R2M1	36%	35%	34%	35%	36%	35%	37%	37%
R3M1	28%	26%	317%	478%	30%	29%	127%	417%
R4M1	28%	26%	311%	550%	29%	30%	95%	298%
R1M2	37%	36%	34%	35%	34%	35%	36%	35%
R2M2	36%	35%	34%	35%	34%	34%	35%	36%
R3M2	28%	26%	318%	477%	28%	27%	191%	1247%
R4M2	28%	26%	322%	548%	27%	28%	195%	1360%
R1VR1	38%	39%	36%	37%	43%	44%	41%	43%
R2VR2	34%	36%	34%	35%	35%	36%	37%	37%
R3VR3	29%	29%	92%	1001%	34%	47%	53%	374%
R4VR4	30%	30%	53%	2108%	33%	41%	48%	251%
R2VR3	34%	35%	36%	33%	32%	34%	43%	41%
R3VR4	30%	30%	87%	1021%	33%	51%	50%	309%
R1F1	37%	38%	35%	36%	42%	44%	45%	42%
R1F2	37%	38%	35%	36%	40%	42%	41%	40%
R4F1	29%	30%	140%	1124%	33%	31%	47%	132%
R4F2	28%	30%	256%	731%	31%	30%	55%	2610%

Appendix E-2 Relative error of SY_{ST} and results of the hypothesis test to determine if the estimated value of SY_{ST} is within 10% of the true value of SY_{ST} (sample size = 100).

Age Sample Size = 100

Relative error of SY_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0%	0%	0%	-1%	-1%	-2%	-2%	0%
R1	-6%	-6%	-5%	-7%	-35%	-36%	-36%	-35%
R2	-6%	-5%	-5%	-7%	-36%	-38%	-36%	-36%
R3	31%	34%	-93%	-97%	18%	22%	-99%	-100%
R4	29%	29%	-95%	-99%	14%	15%	-99%	-100%
R1M1	-1%	-1%	-2%	-2%	-17%	-17%	-18%	-16%
R2M1	2%	2%	3%	2%	-8%	-10%	-8%	-8%
R3M1	32%	36%	-83%	-83%	23%	21%	-96%	-100%
R4M1	36%	37%	-84%	-86%	29%	21%	-94%	-99%
R1M2	-1%	-1%	-1%	-2%	-12%	-13%	-13%	-12%
R2M2	-2%	-2%	-1%	-3%	-13%	-15%	-14%	-14%
R3M2	32%	37%	-83%	-83%	30%	29%	-99%	-100%
R4M2	32%	35%	-85%	-86%	28%	25%	-99%	-100%
R1VR1	-19%	-18%	-19%	-19%	-43%	-44%	-43%	-43%
R2VR2	-4%	-2%	-2%	-3%	-30%	-32%	-31%	-30%
R3VR3	2%	-30%	-87%	-100%	-56%	-89%	-68%	-99%
R4VR4	-8%	-52%	-82%	-100%	-52%	-84%	-64%	-98%
R2VR3	14%	-8%	-22%	-8%	-17%	-43%	-51%	-54%
R3VR4	-7%	-45%	-85%	-100%	-58%	-90%	-68%	-99%
R1F1	-3%	-3%	-3%	-4%	-28%	-28%	-28%	-27%
R1F2	-3%	-3%	-3%	-3%	-37%	-37%	-37%	-37%
R4F1	14%	354%	-89%	-97%	-12%	6%	-42%	-93%
R4F2	23%	445%	-89%	-92%	-5%	38%	-72%	-100%

Results of testing Ho: The relative difference between the true and estimated SY_{ST} is less than the differential.

Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Reject	Fail to Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject
R4F2	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject

Appendix E-3 Average and coefficient of variation (CV) of SY_{ST} across 1000 replicates by reader type(s)/scenarios (sample size = 300).

Age Sample Size = 300
Estimated value of SY_{ST} among reader(s)/scenarios.
True value of SY_{ST} is 29,867

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	28,927	28,969	28,660	28,921	29,080	28,583	28,595	28,542
R1	28,698	28,801	28,434	28,766	20,010	19,683	19,590	19,579
R2	28,746	28,750	28,441	28,714	19,277	19,107	19,042	18,927
R3	40,521	42,290	1,479	54	36,546	37,547	57	0
R4	40,068	40,902	1,437	44	34,930	35,444	74	0
R1M1	28,982	29,011	28,673	28,979	25,711	25,350	25,256	25,201
R2M1	30,332	30,471	30,062	30,324	28,367	27,984	27,932	28,083
R3M1	40,856	43,020	1,902	109	38,328	37,554	1,174	28
R4M1	42,145	43,148	2,186	150	41,067	37,510	1,935	106
R1M2	28,953	29,025	28,687	29,003	26,892	26,537	26,496	26,397
R2M2	29,024	29,141	28,761	29,033	26,506	26,166	26,088	26,253
R3M2	40,910	43,068	1,878	111	40,277	39,562	331	2
R4M2	40,839	42,483	1,859	109	39,848	38,323	278	1
R1VR1	23,383	23,440	23,132	23,400	17,033	16,939	16,851	16,737
R2VR2	28,960	29,059	28,728	28,982	21,391	21,005	21,005	20,922
R3VR3	31,416	21,685	3,801	0	13,408	3,384	9,458	36
R4VR4	28,330	14,749	3,477	0	14,985	4,856	10,906	177
R2VR3	34,983	27,991	22,239	28,323	25,610	17,473	14,687	13,888
R3VR4	28,752	17,018	4,310	0	12,874	3,122	9,974	82
R1F1	28,066	28,094	27,738	28,055	20,980	20,663	20,613	20,506
R1F2	28,059	28,128	27,799	28,093	17,969	17,777	17,719	17,636
R4F1	35,179	141,872	3,305	11	27,299	32,736	17,668	1,645
R4F2	38,021	171,422	2,596	35	29,239	42,349	8,264	0

Estimated value of the CV of SY_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	25%	24%	25%	26%	25%	25%	24%	25%
R1	26%	24%	26%	27%	27%	27%	26%	28%
R2	26%	25%	26%	27%	27%	27%	26%	27%
R3	24%	21%	84%	599%	23%	22%	400%	--
R4	24%	22%	87%	555%	23%	22%	357%	--
R1M1	26%	24%	25%	26%	27%	27%	26%	27%
R2M1	25%	24%	25%	26%	26%	27%	26%	27%
R3M1	24%	21%	72%	376%	24%	23%	97%	771%
R4M1	24%	22%	66%	339%	24%	23%	72%	462%
R1M2	26%	24%	25%	26%	26%	26%	25%	27%
R2M2	26%	24%	25%	26%	26%	26%	25%	27%
R3M2	24%	21%	72%	381%	23%	22%	178%	2247%
R4M2	24%	21%	72%	392%	23%	22%	202%	2540%
R1VR1	26%	25%	26%	27%	29%	30%	30%	30%
R2VR2	25%	24%	25%	26%	26%	26%	26%	27%
R3VR3	24%	22%	82%	--	27%	36%	35%	623%
R4VR4	24%	23%	73%	--	26%	30%	33%	309%
R2VR3	26%	25%	26%	27%	25%	26%	29%	30%
R3VR4	24%	23%	73%	--	27%	37%	35%	427%
R1F1	26%	24%	25%	27%	30%	29%	29%	29%
R1F2	26%	24%	25%	27%	28%	28%	28%	28%
R4F1	24%	23%	51%	1601%	25%	24%	30%	99%
R4F2	24%	24%	59%	748%	24%	22%	37%	--

Appendix E-4 Relative error of SY_{ST} and results of the hypothesis test to determine if the estimated value of SY_{ST} is within 10% of the true value of SY_{ST} (sample size = 300).

Age Sample Size = 300
Relative error of SY_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-3%	-3%	-4%	-3%	-3%	-4%	-4%	-4%
R1	-4%	-4%	-5%	-4%	-33%	-34%	-34%	-34%
R2	-4%	-4%	-5%	-4%	-35%	-36%	-36%	-37%
R3	36%	42%	-95%	-100%	22%	26%	-100%	-100%
R4	34%	37%	-95%	-100%	17%	19%	-100%	-100%
R1M1	-3%	-3%	-4%	-3%	-14%	-15%	-15%	-16%
R2M1	2%	2%	1%	2%	-5%	-6%	-6%	-6%
R3M1	37%	44%	-94%	-100%	28%	26%	-96%	-100%
R4M1	41%	44%	-93%	-99%	37%	26%	-94%	-100%
R1M2	-3%	-3%	-4%	-3%	-10%	-11%	-11%	-12%
R2M2	-3%	-2%	-4%	-3%	-11%	-12%	-13%	-12%
R3M2	37%	44%	-94%	-100%	35%	32%	-99%	-100%
R4M2	37%	42%	-94%	-100%	33%	28%	-99%	-100%
R1VR1	-22%	-22%	-23%	-22%	-43%	-43%	-44%	-44%
R2VR2	-3%	-3%	-4%	-3%	-28%	-30%	-30%	-30%
R3VR3	5%	-27%	-87%	-100%	-55%	-89%	-68%	-100%
R4VR4	-5%	-51%	-88%	-100%	-50%	-84%	-63%	-99%
R2VR3	17%	-6%	-26%	-5%	-14%	-41%	-51%	-54%
R3VR4	-4%	-43%	-86%	-100%	-57%	-90%	-67%	-100%
R1F1	-6%	-6%	-7%	-6%	-30%	-31%	-31%	-31%
R1F2	-6%	-6%	-7%	-6%	-40%	-40%	-41%	-41%
R4F1	18%	375%	-89%	-100%	-9%	10%	-41%	-94%
R4F2	27%	474%	-91%	-100%	-2%	42%	-72%	-100%

Results of testing Ho: The relative difference between the true and estimated SY_{ST} is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Reject	Fail to Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4F2	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject

Appendix E-5 Average and coefficient of variation (CV) of SY_{ST} across 1000 replicates by reader type(s)/scenarios (sample size = 900).

Age Sample Size = 900
Estimated value of SY_{ST} among reader(s)/scenarios.
True value of SY_{ST} is 29,867

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	29,096	29,309	29,143	29,604	29,336	29,141	29,030	29,407
R1	28,864	29,084	28,961	29,389	20,052	19,966	19,885	20,067
R2	28,767	28,954	28,917	29,408	19,465	19,370	19,232	19,487
R3	41,154	42,959	1,494	22	36,866	38,990	39	0
R4	40,713	41,575	1,434	18	35,595	36,940	37	0
R1M1	29,145	29,342	29,183	29,642	25,935	25,847	25,621	26,018
R2M1	30,565	30,739	30,594	31,086	28,702	28,556	28,476	28,851
R3M1	41,398	43,652	1,929	62	39,093	39,358	1,267	3
R4M1	42,739	43,958	2,195	102	41,655	39,304	2,019	35
R1M2	29,160	29,341	29,203	29,676	27,039	27,001	26,781	27,204
R2M2	29,270	29,403	29,293	29,746	26,685	26,619	26,528	26,824
R3M2	41,427	43,714	1,906	58	40,817	41,146	341	0
R4M2	41,345	43,216	1,863	57	40,313	39,987	291	0
R1VR1	23,511	23,634	23,545	23,870	17,145	17,130	17,032	17,275
R2VR2	29,137	29,368	29,225	29,681	21,415	21,339	21,282	21,426
R3VR3	31,778	21,905	3,790	0	13,402	3,519	9,701	7
R4VR4	28,692	14,949	2,749	0	15,014	5,015	11,040	98
R2VR3	35,155	28,259	22,674	28,953	25,757	17,781	14,817	14,272
R3VR4	29,098	17,196	4,294	0	12,979	3,199	10,107	27
R1F1	28,223	28,399	28,247	28,664	21,273	21,044	21,045	21,189
R1F2	28,212	28,414	28,292	28,741	18,140	17,999	18,005	18,200
R4F1	35,602	144,245	2,954	0	27,551	33,650	17,895	1,699
R4F2	38,456	174,925	2,357	0	29,521	43,417	8,454	0

Estimated value of the CV of SY_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	21%	23%	22%	22%	23%	23%	22%	22%
R1	22%	23%	22%	22%	25%	24%	24%	23%
R2	22%	23%	23%	23%	25%	24%	24%	23%
R3	20%	22%	73%	789%	22%	22%	430%	--
R4	21%	22%	76%	827%	22%	22%	459%	--
R1M1	22%	23%	22%	22%	24%	24%	23%	23%
R2M1	21%	23%	22%	22%	24%	24%	23%	23%
R3M1	20%	22%	62%	459%	22%	22%	85%	1649%
R4M1	21%	23%	58%	374%	22%	22%	65%	593%
R1M2	22%	23%	22%	22%	24%	24%	23%	23%
R2M2	22%	23%	22%	22%	24%	24%	23%	23%
R3M2	20%	22%	63%	515%	22%	22%	166%	--
R4M2	21%	22%	64%	503%	22%	22%	181%	--
R1VR1	22%	23%	23%	23%	26%	26%	26%	25%
R2VR2	21%	23%	22%	22%	25%	24%	23%	23%
R3VR3	21%	22%	55%	--	25%	32%	29%	1045%
R4VR4	21%	23%	61%	--	25%	28%	28%	318%
R2VR3	22%	23%	23%	23%	23%	24%	26%	25%
R3VR4	21%	23%	51%	--	26%	34%	29%	535%
R1F1	22%	23%	22%	22%	25%	24%	25%	24%
R1F2	21%	23%	22%	22%	26%	25%	25%	24%
R4F1	20%	24%	58%	--	23%	22%	26%	79%
R4F2	20%	24%	64%	--	23%	22%	32%	--

Appendix E-6 Relative error of SY_{ST} and results of the hypothesis test to determine if the estimated value of SY_{ST} is within 10% of the true value of SY_{ST} (sample size = 900).

Age Sample Size = 900

Relative error of SY_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-3%	-2%	-2%	-1%	-2%	-2%	-3%	-2%
R1	-3%	-3%	-3%	-2%	-33%	-33%	-33%	-33%
R2	-4%	-3%	-3%	-2%	-35%	-35%	-36%	-35%
R3	38%	44%	-95%	-100%	23%	31%	-100%	-100%
R4	36%	39%	-95%	-100%	19%	24%	-100%	-100%
R1M1	-2%	-2%	-2%	-1%	-13%	-13%	-14%	-13%
R2M1	2%	3%	2%	4%	-4%	-4%	-5%	-3%
R3M1	39%	46%	-94%	-100%	31%	32%	-96%	-100%
R4M1	43%	47%	-93%	-100%	39%	32%	-93%	-100%
R1M2	-2%	-2%	-2%	-1%	-9%	-10%	-10%	-9%
R2M2	-2%	-2%	-2%	0%	-11%	-11%	-11%	-10%
R3M2	39%	46%	-94%	-100%	37%	38%	-99%	-100%
R4M2	38%	45%	-94%	-100%	35%	34%	-99%	-100%
R1VR1	-21%	-21%	-21%	-20%	-43%	-43%	-43%	-42%
R2VR2	-2%	-2%	-2%	-1%	-28%	-29%	-29%	-28%
R3VR3	6%	-27%	-87%	-100%	-55%	-88%	-68%	-100%
R4VR4	-4%	-50%	-91%	-100%	-50%	-83%	-63%	-100%
R2VR3	18%	-5%	-24%	-3%	-14%	-40%	-50%	-52%
R3VR4	-3%	-42%	-86%	-100%	-57%	-89%	-66%	-100%
R1F1	-6%	-5%	-5%	-4%	-29%	-30%	-30%	-29%
R1F2	-6%	-5%	-5%	-4%	-39%	-40%	-40%	-39%
R4F1	19%	383%	-90%	-100%	-8%	13%	-40%	-94%
R4F2	29%	486%	-92%	-100%	-1%	45%	-72%	-100%

Results of testing Ho: The relative difference between the true and estimated SY_{ST} is less than the differential.

Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Fail to Reject
R3M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Reject	Fail to Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R4F2	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject

Appendix E-7 Average and coefficient of variation (CV) of SY_{m+} across 1000 replicates by reader type(s)/scenarios (sample size = 100).

Age Sample Size = 100
Estimated value of SY_{m+} among reader(s)/scenarios.
True value of SY_{m+} is 17,019

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	16,879	16,911	16,888	16,873	16,907	16,754	16,780	16,915
R1	16,685	16,811	16,816	16,701	15,522	15,427	15,364	15,472
R2	16,778	16,947	16,837	16,763	15,371	15,229	15,356	15,354
R3	18,006	16,243	10,443	13,132	17,441	15,529	9,815	12,284
R4	17,920	15,877	10,338	12,988	17,153	15,045	9,836	12,279
R1M1	16,820	16,878	16,791	16,768	16,455	16,444	16,328	16,523
R2M1	17,006	17,022	17,053	16,988	17,052	16,871	16,960	17,031
R3M1	18,044	16,380	11,297	14,867	17,479	15,283	10,410	13,073
R4M1	18,301	16,356	11,233	14,511	17,806	15,130	10,690	13,399
R1M2	16,812	16,884	16,815	16,781	16,956	16,948	16,830	16,971
R2M2	16,765	16,775	16,808	16,748	16,978	16,767	16,830	16,877
R3M2	18,066	16,400	11,290	14,851	18,140	15,927	9,891	12,343
R4M2	18,058	16,260	11,115	14,351	18,014	15,667	9,870	12,290
R1VR1	15,720	15,840	15,727	15,701	14,666	14,585	14,582	14,584
R2VR2	16,597	16,825	16,755	16,723	15,793	15,651	15,662	15,760
R3VR3	16,233	11,191	11,069	5,968	12,525	6,149	13,159	9,398
R4VR4	15,630	9,204	11,690	6,358	12,913	6,758	13,425	9,717
R2VR3	18,191	16,915	15,491	16,601	16,528	14,341	14,218	13,991
R3VR4	15,663	9,857	11,376	6,026	12,425	6,065	13,220	9,553
R1F1	16,700	16,735	16,692	16,696	15,313	15,264	15,269	15,304
R1F2	16,714	16,749	16,705	16,716	14,803	14,755	14,728	14,758
R4F1	16,977	31,179	10,937	8,663	16,332	17,289	14,938	10,533
R4F2	17,537	33,695	10,849	12,355	16,921	19,274	12,234	7,950

Estimated value of the CV of SY_{m+} among reader(s)/scenarios.

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	22%	21%	20%	21%	20%	21%	21%	21%
R1	20%	19%	19%	19%	19%	19%	19%	19%
R2	20%	19%	19%	19%	19%	18%	20%	19%
R3	19%	19%	24%	30%	18%	20%	15%	15%
R4	19%	19%	17%	21%	18%	20%	15%	15%
R1M1	21%	21%	20%	20%	19%	20%	21%	20%
R2M1	21%	20%	20%	20%	20%	19%	21%	20%
R3M1	19%	19%	44%	61%	19%	21%	15%	15%
R4M1	19%	19%	41%	56%	19%	21%	16%	16%
R1M2	21%	21%	20%	20%	19%	20%	20%	20%
R2M2	20%	20%	20%	20%	19%	19%	20%	20%
R3M2	19%	19%	45%	61%	18%	20%	15%	15%
R4M2	19%	19%	40%	56%	18%	20%	15%	15%
R1VR1	22%	21%	20%	21%	22%	22%	21%	21%
R2VR2	19%	20%	19%	20%	19%	19%	19%	19%
R3VR3	19%	20%	23%	29%	17%	18%	21%	19%
R4VR4	19%	20%	17%	18%	17%	18%	21%	19%
R2VR3	20%	19%	20%	19%	18%	18%	20%	19%
R3VR4	19%	20%	23%	25%	17%	18%	20%	19%
R1F1	22%	21%	20%	21%	22%	23%	23%	22%
R1F2	22%	21%	20%	21%	21%	22%	22%	21%
R4F1	19%	20%	18%	57%	19%	18%	23%	21%
R4F2	19%	20%	27%	53%	18%	18%	22%	19%

Appendix E-8 Relative error of SY_{m+} and results of the hypothesis test to determine if the estimated value of SY_{m+} is within 10% of the true value of SY_{m+} (sample size = 100).

Age Sample Size = 100
Relative error of SY_{m+} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-1%	-1%	-1%	-1%	-1%	-2%	-1%	-1%
R1	-2%	-1%	-1%	-2%	-9%	-9%	-10%	-9%
R2	-1%	0%	-1%	-2%	-10%	-11%	-10%	-10%
R3	6%	-5%	-39%	-23%	2%	-9%	-42%	-28%
R4	5%	-7%	-39%	-24%	1%	-12%	-42%	-28%
R1M1	-1%	-1%	-1%	-1%	-3%	-3%	-4%	-3%
R2M1	0%	0%	0%	0%	0%	-1%	0%	0%
R3M1	6%	-4%	-34%	-13%	3%	-10%	-39%	-23%
R4M1	8%	-4%	-34%	-15%	5%	-11%	-37%	-21%
R1M2	-1%	-1%	-1%	-1%	0%	0%	-1%	0%
R2M2	-1%	-1%	-1%	-2%	0%	-1%	-1%	-1%
R3M2	6%	-4%	-34%	-13%	7%	-6%	-42%	-27%
R4M2	6%	-4%	-35%	-16%	6%	-8%	-42%	-28%
R1VR1	-8%	-7%	-8%	-8%	-14%	-14%	-14%	-14%
R2VR2	-2%	-1%	-2%	-2%	-7%	-8%	-8%	-7%
R3VR3	-5%	-34%	-35%	-65%	-26%	-64%	-23%	-45%
R4VR4	-8%	-46%	-31%	-63%	-24%	-60%	-21%	-43%
R2VR3	7%	-1%	-9%	-2%	-3%	-16%	-16%	-18%
R3VR4	-8%	-42%	-33%	-65%	-27%	-64%	-22%	-44%
R1F1	-2%	-2%	-2%	-2%	-10%	-10%	-10%	-10%
R1F2	-2%	-2%	-2%	-2%	-13%	-13%	-13%	-13%
R4F1	0%	83%	-36%	-49%	-4%	2%	-12%	-38%
R4F2	3%	98%	-36%	-27%	-1%	13%	-28%	-53%

Results of testing Ho: The relative difference between the true and estimated SY_{m+} is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Fail to Reject	Fail to Reject	Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Fail to Reject	Fail to Reject	Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject
R3VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject

Appendix E-9 Average and coefficient of variation (CV) of SY_{m+} across 1000 replicates by reader type(s)/scenarios (sample size = 300).

Age Sample Size = 300
Estimated value of SY_{m+} among reader(s)/scenarios.
True value of SY_{m+} is 17,019

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	16,568	16,598	16,420	16,484	16,582	16,375	16,449	16,372
R1	16,954	17,009	16,811	16,895	15,671	15,499	15,518	15,460
R2	17,062	17,077	16,901	16,973	15,480	15,346	15,384	15,304
R3	18,428	16,785	10,321	12,857	17,733	15,741	9,875	12,131
R4	18,335	16,442	10,330	12,868	17,358	15,214	9,887	12,172
R1M1	16,644	16,673	16,487	16,562	16,722	16,550	16,587	16,505
R2M1	16,947	17,005	16,795	16,855	17,312	17,119	17,172	17,158
R3M1	18,461	16,929	10,381	12,981	17,842	15,508	10,493	12,921
R4M1	18,718	16,910	10,474	13,090	18,366	15,358	10,788	13,296
R1M2	16,639	16,679	16,492	16,572	17,158	16,993	17,040	16,945
R2M2	16,691	16,744	16,540	16,611	17,103	16,927	16,963	16,953
R3M2	18,480	16,943	10,373	12,962	18,477	16,100	9,969	12,209
R4M2	18,468	16,803	10,371	12,967	18,388	15,795	9,939	12,179
R1VR1	15,396	15,433	15,251	15,327	14,634	14,547	14,566	14,473
R2VR2	16,712	16,762	16,577	16,640	15,946	15,747	15,815	15,720
R3VR3	16,594	11,463	11,118	5,633	12,661	6,055	13,234	9,300
R4VR4	15,911	9,355	10,165	5,505	13,071	6,687	13,542	9,595
R2VR3	18,512	17,115	15,100	16,783	16,729	14,390	14,340	13,952
R3VR4	15,987	10,062	11,266	5,773	12,508	5,970	13,386	9,446
R1F1	16,386	16,413	16,224	16,301	14,951	14,790	14,832	14,737
R1F2	16,388	16,426	16,243	16,314	14,335	14,208	14,239	14,151
R4F1	17,347	31,986	10,934	5,646	16,612	17,426	15,112	10,408
R4F2	17,937	34,655	10,659	6,379	17,170	19,416	12,297	7,866

Estimated value of the CV of SY_{m+} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	16%	15%	16%	17%	16%	16%	15%	15%
R1	16%	16%	16%	17%	16%	16%	16%	16%
R2	16%	16%	16%	17%	15%	16%	15%	16%
R3	17%	17%	14%	15%	16%	17%	14%	14%
R4	17%	17%	14%	15%	16%	17%	14%	14%
R1M1	16%	15%	16%	17%	16%	16%	16%	17%
R2M1	16%	15%	16%	17%	16%	16%	16%	16%
R3M1	17%	17%	14%	15%	17%	18%	14%	14%
R4M1	17%	17%	14%	15%	17%	18%	14%	14%
R1M2	16%	15%	16%	17%	16%	16%	16%	16%
R2M2	16%	15%	16%	17%	16%	16%	16%	16%
R3M2	17%	17%	14%	15%	16%	17%	13%	14%
R4M2	17%	17%	14%	15%	16%	17%	14%	14%
R1VR1	16%	15%	16%	17%	16%	17%	17%	17%
R2VR2	16%	15%	16%	17%	15%	16%	15%	16%
R3VR3	17%	16%	21%	18%	15%	16%	16%	16%
R4VR4	17%	17%	20%	18%	15%	16%	16%	16%
R2VR3	17%	16%	16%	17%	16%	15%	16%	16%
R3VR4	17%	16%	21%	18%	15%	16%	16%	16%
R1F1	16%	15%	16%	17%	17%	17%	17%	17%
R1F2	16%	15%	16%	17%	16%	16%	16%	16%
R4F1	17%	16%	14%	22%	16%	16%	17%	16%
R4F2	17%	17%	14%	44%	16%	16%	16%	16%

Appendix E-10 Relative error of SY_{m+} and results of the hypothesis test to determine if the estimated value of SY_{m+} is within 10% of the true value of SY_{m+} (sample size = 300).

Age Sample Size = 300
Relative error of SY_{m+} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-3%	-2%	-4%	-3%	-3%	-4%	-3%	-4%
R1	0%	0%	-1%	-1%	-8%	-9%	-9%	-9%
R2	0%	0%	-1%	0%	-9%	-10%	-10%	-10%
R3	8%	-1%	-39%	-24%	4%	-8%	-42%	-29%
R4	8%	-3%	-39%	-24%	2%	-11%	-42%	-28%
R1M1	-2%	-2%	-3%	-3%	-2%	-3%	-3%	-3%
R2M1	0%	0%	-1%	-1%	2%	1%	1%	1%
R3M1	8%	-1%	-39%	-24%	5%	-9%	-38%	-24%
R4M1	10%	-1%	-38%	-23%	8%	-10%	-37%	-22%
R1M2	-2%	-2%	-3%	-3%	1%	0%	0%	0%
R2M2	-2%	-2%	-3%	-2%	0%	-1%	0%	0%
R3M2	9%	0%	-39%	-24%	9%	-5%	-41%	-28%
R4M2	9%	-1%	-39%	-24%	8%	-7%	-42%	-28%
R1VR1	-10%	-9%	-10%	-10%	-14%	-15%	-14%	-15%
R2VR2	-2%	-2%	-3%	-2%	-6%	-7%	-7%	-8%
R3VR3	-2%	-33%	-35%	-67%	-26%	-64%	-22%	-45%
R4VR4	-7%	-45%	-40%	-68%	-23%	-61%	-20%	-44%
R2VR3	9%	1%	-11%	-1%	-2%	-15%	-16%	-18%
R3VR4	-6%	-41%	-34%	-66%	-27%	-65%	-21%	-44%
R1F1	-4%	-4%	-5%	-4%	-12%	-13%	-13%	-13%
R1F2	-4%	-3%	-5%	-4%	-16%	-17%	-16%	-17%
R4F1	2%	88%	-36%	-67%	-2%	2%	-11%	-39%
R4F2	5%	104%	-37%	-63%	1%	14%	-28%	-54%

Results of testing Ho: The relative difference between the true and estimated SY_{m+} is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject
R3VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject

Appendix E-11 Average and coefficient of variation (CV) of SY_{m+} across 1000 replicates by reader type(s)/scenarios (sample size = 900).

Age Sample Size = 900
Estimated value of SY_{m+} among reader(s)/scenarios.
True value of SY_{m+} is 17,019

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	16,591	16,643	16,549	16,757	16,664	16,552	16,511	16,662
R1	16,989	17,050	16,959	17,161	15,705	15,616	15,572	15,683
R2	17,042	17,092	17,032	17,254	15,559	15,468	15,421	15,542
R3	18,560	16,905	10,345	13,033	17,834	16,133	9,892	12,267
R4	18,464	16,572	10,348	13,043	17,540	15,633	9,889	12,278
R1M1	16,672	16,717	16,623	16,831	16,814	16,726	16,643	16,813
R2M1	16,985	17,028	16,937	17,149	17,414	17,319	17,280	17,437
R3M1	18,568	17,039	10,405	13,166	18,051	15,996	10,529	13,070
R4M1	18,834	17,066	10,491	13,280	18,521	15,838	10,808	13,441
R1M2	16,677	16,720	16,632	16,845	17,233	17,158	17,080	17,252
R2M2	16,735	16,766	16,685	16,890	17,169	17,092	17,056	17,194
R3M2	18,579	17,061	10,395	13,143	18,626	16,527	9,981	12,346
R4M2	18,563	16,935	10,383	13,147	18,520	16,246	9,946	12,305
R1VR1	15,414	15,447	15,373	15,548	14,705	14,635	14,587	14,718
R2VR2	16,740	16,801	16,709	16,919	15,970	15,881	15,855	15,943
R3VR3	16,670	11,491	11,200	5,745	12,679	6,130	13,304	9,373
R4VR4	15,988	9,387	9,641	5,381	13,097	6,773	13,572	9,734
R2VR3	18,538	17,153	15,237	17,051	16,792	14,523	14,350	14,163
R3VR4	16,058	10,081	11,329	5,863	12,563	6,020	13,415	9,532
R1F1	16,405	16,449	16,360	16,554	15,058	14,935	14,923	15,011
R1F2	16,405	16,459	16,375	16,578	14,414	14,310	14,303	14,409
R4F1	17,433	32,176	10,586	5,418	16,704	17,692	15,163	10,566
R4F2	18,024	34,904	10,378	5,256	17,271	19,699	12,362	7,958

Estimated value of the CV of SY_{m+} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	14%	15%	15%	15%	16%	15%	15%	15%
R1	14%	15%	15%	15%	16%	15%	15%	15%
R2	14%	16%	15%	15%	16%	15%	15%	15%
R3	15%	18%	14%	14%	16%	17%	14%	14%
R4	15%	18%	14%	14%	16%	17%	14%	14%
R1M1	14%	15%	15%	15%	16%	16%	15%	15%
R2M1	14%	15%	15%	15%	16%	16%	15%	15%
R3M1	15%	18%	14%	14%	16%	18%	14%	14%
R4M1	15%	18%	14%	14%	17%	18%	14%	14%
R1M2	14%	15%	15%	15%	16%	16%	15%	15%
R2M2	14%	15%	15%	15%	16%	16%	15%	15%
R3M2	15%	18%	14%	14%	16%	17%	14%	14%
R4M2	15%	18%	14%	14%	16%	18%	14%	14%
R1VR1	14%	15%	15%	15%	16%	16%	16%	15%
R2VR2	14%	15%	15%	15%	16%	15%	15%	15%
R3VR3	15%	17%	16%	15%	16%	16%	15%	15%
R4VR4	15%	17%	16%	15%	16%	16%	15%	15%
R2VR3	15%	16%	15%	15%	16%	15%	15%	14%
R3VR4	15%	17%	16%	15%	16%	16%	15%	14%
R1F1	14%	15%	15%	15%	16%	16%	16%	15%
R1F2	14%	15%	15%	15%	16%	15%	15%	15%
R4F1	15%	18%	16%	16%	16%	16%	16%	15%
R4F2	15%	18%	16%	15%	16%	16%	15%	14%

Appendix E-12 Relative error of SY_{m+} and results of the hypothesis test to determine if the estimated value of SY_{m+} is within 10% of the true value of SY_{m+} (sample size = 900).

Age Sample Size = 900
Relative error of SY_{m+} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-3%	-2%	-3%	-2%	-2%	-3%	-3%	-2%
R1	0%	0%	0%	1%	-8%	-8%	-9%	-8%
R2	0%	0%	0%	1%	-9%	-9%	-9%	-9%
R3	9%	-1%	-39%	-23%	5%	-5%	-42%	-28%
R4	8%	-3%	-39%	-23%	3%	-8%	-42%	-28%
R1M1	-2%	-2%	-2%	-1%	-1%	-2%	-2%	-1%
R2M1	0%	0%	0%	1%	2%	2%	2%	2%
R3M1	9%	0%	-39%	-23%	6%	-6%	-38%	-23%
R4M1	11%	0%	-38%	-22%	9%	-7%	-36%	-21%
R1M2	-2%	-2%	-2%	-1%	1%	1%	0%	1%
R2M2	-2%	-1%	-2%	-1%	1%	0%	0%	1%
R3M2	9%	0%	-39%	-23%	9%	-3%	-41%	-27%
R4M2	9%	0%	-39%	-23%	9%	-5%	-42%	-28%
R1VR1	-9%	-9%	-10%	-9%	-14%	-14%	-14%	-14%
R2VR2	-2%	-1%	-2%	-1%	-6%	-7%	-7%	-6%
R3VR3	-2%	-32%	-34%	-66%	-26%	-64%	-22%	-45%
R4VR4	-6%	-45%	-43%	-68%	-23%	-60%	-20%	-43%
R2VR3	9%	1%	-10%	0%	-1%	-15%	-16%	-17%
R3VR4	-6%	-41%	-33%	-66%	-26%	-65%	-21%	-44%
R1F1	-4%	-3%	-4%	-3%	-12%	-12%	-12%	-12%
R1F2	-4%	-3%	-4%	-3%	-15%	-16%	-16%	-15%
R4F1	2%	89%	-38%	-68%	-2%	4%	-11%	-38%
R4F2	6%	105%	-39%	-69%	1%	16%	-27%	-53%

Results of testing Ho: The relative difference between the true and estimated SY_{m+} is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject
R3VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject

Appendix E-13 Average and coefficient of variation (CV) of F_{ST} across 1000 replicates by reader type(s)/scenarios (sample size = 100).

Age Sample Size = 100
Estimated value of F_{ST} among reader(s)/scenarios.
True value of F_{ST} is 0.402

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.397	0.394	0.398	0.395	0.395	0.390	0.393	0.395
R1	0.369	0.369	0.373	0.368	0.257	0.253	0.255	0.256
R2	0.367	0.367	0.369	0.364	0.250	0.246	0.251	0.250
R3	0.416	0.448	0.033	0.013	0.390	0.415	0.003	0.000
R4	0.413	0.437	0.028	0.006	0.380	0.401	0.003	0.000
R1M1	0.392	0.390	0.392	0.389	0.316	0.314	0.313	0.318
R2M1	0.403	0.400	0.405	0.401	0.339	0.335	0.340	0.340
R3M1	0.418	0.454	0.068	0.076	0.402	0.419	0.021	0.002
R4M1	0.427	0.456	0.069	0.061	0.417	0.421	0.033	0.005
R1M2	0.392	0.391	0.393	0.390	0.332	0.331	0.330	0.332
R2M2	0.390	0.387	0.392	0.388	0.329	0.323	0.328	0.326
R3M2	0.418	0.455	0.068	0.075	0.416	0.434	0.008	0.000
R4M2	0.418	0.450	0.062	0.066	0.412	0.425	0.007	0.000
R1VR1	0.339	0.338	0.340	0.336	0.245	0.242	0.244	0.244
R2VR2	0.385	0.386	0.389	0.385	0.272	0.268	0.272	0.272
R3VR3	0.346	0.286	0.063	0.001	0.183	0.064	0.140	0.003
R4VR4	0.322	0.218	0.092	0.000	0.198	0.087	0.159	0.007
R2VR3	0.417	0.349	0.326	0.364	0.305	0.227	0.208	0.198
R3VR4	0.325	0.241	0.074	0.001	0.179	0.060	0.143	0.005
R1F1	0.387	0.385	0.388	0.385	0.301	0.301	0.302	0.304
R1F2	0.388	0.386	0.389	0.386	0.275	0.274	0.274	0.275
R4F1	0.375	1.227	0.060	0.014	0.312	0.370	0.239	0.034
R4F2	0.396	1.464	0.055	0.039	0.329	0.452	0.132	0.000

Estimated value of the CV of F_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	21%	21%	20%	20%	19%	20%	20%	21%
R1	20%	21%	20%	19%	22%	22%	22%	23%
R2	20%	20%	20%	19%	23%	22%	23%	23%
R3	16%	14%	213%	1109%	16%	15%	310%	2344%
R4	16%	15%	153%	1090%	16%	15%	291%	2180%
R1M1	21%	21%	20%	20%	22%	22%	22%	23%
R2M1	20%	20%	20%	20%	21%	21%	22%	22%
R3M1	16%	14%	249%	505%	17%	16%	118%	414%
R4M1	16%	14%	239%	559%	17%	17%	88%	291%
R1M2	21%	21%	20%	20%	20%	20%	20%	21%
R2M2	20%	20%	20%	20%	20%	20%	20%	21%
R3M2	16%	14%	251%	496%	16%	15%	184%	1285%
R4M2	16%	14%	252%	622%	16%	15%	190%	1366%
R1VR1	22%	23%	21%	21%	25%	26%	24%	26%
R2VR2	20%	21%	20%	20%	21%	22%	22%	23%
R3VR3	17%	17%	70%	967%	23%	40%	36%	358%
R4VR4	18%	19%	41%	1996%	22%	32%	32%	236%
R2VR3	20%	21%	21%	19%	19%	21%	27%	27%
R3VR4	17%	18%	62%	1014%	22%	43%	34%	292%
R1F1	21%	22%	20%	20%	26%	26%	27%	26%
R1F2	21%	22%	20%	20%	23%	24%	24%	24%
R4F1	16%	21%	90%	1247%	20%	19%	28%	114%
R4F2	16%	22%	170%	761%	18%	17%	39%	2584%

Appendix E-14 Relative error of F_{ST} and results of the hypothesis test to determine if the estimated value of F_{ST} is within 10% of the true value of F_{ST} (sample size = 100).

Age Sample Size = 100
Relative error of F_{ST} among reader(s)/scenarios.

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-1%	-2%	-1%	-2%	-2%	-3%	-2%	-2%
R1	-8%	-8%	-7%	-8%	-36%	-37%	-37%	-36%
R2	-9%	-9%	-8%	-9%	-38%	-39%	-37%	-38%
R3	3%	12%	-92%	-97%	-3%	3%	-99%	-100%
R4	3%	9%	-93%	-99%	-5%	0%	-99%	-100%
R1M1	-2%	-3%	-2%	-3%	-21%	-22%	-22%	-21%
R2M1	0%	0%	1%	0%	-16%	-17%	-15%	-15%
R3M1	4%	13%	-83%	-81%	0%	4%	-95%	-99%
R4M1	6%	13%	-83%	-85%	4%	5%	-92%	-99%
R1M2	-2%	-3%	-2%	-3%	-17%	-18%	-18%	-17%
R2M2	-3%	-4%	-2%	-3%	-18%	-20%	-18%	-19%
R3M2	4%	13%	-83%	-81%	4%	8%	-98%	-100%
R4M2	4%	12%	-84%	-84%	2%	6%	-98%	-100%
R1VR1	-16%	-16%	-16%	-16%	-39%	-40%	-39%	-39%
R2VR2	-4%	-4%	-3%	-4%	-32%	-33%	-32%	-32%
R3VR3	-14%	-29%	-84%	-100%	-54%	-84%	-65%	-99%
R4VR4	-20%	-46%	-77%	-100%	-51%	-78%	-60%	-98%
R2VR3	4%	-13%	-19%	-9%	-24%	-43%	-48%	-51%
R3VR4	-19%	-40%	-82%	-100%	-56%	-85%	-64%	-99%
R1F1	-4%	-4%	-3%	-4%	-25%	-25%	-25%	-24%
R1F2	-3%	-4%	-3%	-4%	-32%	-32%	-32%	-32%
R4F1	-7%	205%	-85%	-96%	-22%	-8%	-40%	-92%
R4F2	-1%	264%	-86%	-90%	-18%	13%	-67%	-100%

Results of testing Ho: The relative difference between the true and estimated F_{ST} is less than the differential.
Differential= 10%

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject

Appendix E-15 Average and coefficient of variation (CV) of F_{ST} across 1000 replicates by reader type(s)/scenarios (sample size = 300).

Age Sample Size = 300
Estimated value of F_{ST} among reader(s)/scenarios.
True value of F_{ST} is 0.402

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.393	0.394	0.393	0.395	0.396	0.394	0.392	0.393
R1	0.376	0.377	0.376	0.379	0.264	0.262	0.260	0.261
R2	0.373	0.374	0.373	0.375	0.256	0.256	0.254	0.254
R3	0.425	0.466	0.027	0.001	0.400	0.431	0.001	0.000
R4	0.422	0.455	0.026	0.001	0.388	0.415	0.001	0.000
R1M1	0.392	0.392	0.391	0.393	0.327	0.325	0.324	0.324
R2M1	0.404	0.406	0.405	0.407	0.352	0.350	0.349	0.351
R3M1	0.426	0.472	0.035	0.002	0.414	0.435	0.021	0.000
R4M1	0.436	0.474	0.040	0.002	0.435	0.438	0.035	0.002
R1M2	0.391	0.392	0.391	0.394	0.341	0.339	0.338	0.338
R2M2	0.391	0.392	0.391	0.393	0.336	0.335	0.334	0.336
R3M2	0.427	0.472	0.035	0.002	0.427	0.448	0.006	0.000
R4M2	0.426	0.468	0.034	0.002	0.424	0.439	0.005	0.000
R1VR1	0.335	0.335	0.334	0.336	0.249	0.249	0.247	0.247
R2VR2	0.389	0.390	0.389	0.391	0.280	0.278	0.277	0.277
R3VR3	0.354	0.296	0.063	0.000	0.189	0.066	0.143	0.001
R4VR4	0.328	0.225	0.064	0.000	0.204	0.090	0.163	0.003
R2VR3	0.424	0.357	0.323	0.375	0.313	0.235	0.213	0.201
R3VR4	0.332	0.250	0.072	0.000	0.183	0.061	0.149	0.001
R1F1	0.384	0.385	0.384	0.386	0.304	0.302	0.301	0.301
R1F2	0.385	0.386	0.385	0.387	0.272	0.271	0.270	0.270
R4F1	0.383	1.274	0.060	0.000	0.323	0.382	0.248	0.028
R4F2	0.405	1.531	0.048	0.001	0.338	0.465	0.136	0.000

Estimated value of the CV of F_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	14%	13%	14%	14%	14%	13%	13%	13%
R1	14%	13%	14%	14%	16%	15%	15%	16%
R2	14%	13%	14%	14%	16%	15%	15%	15%
R3	12%	11%	78%	599%	12%	11%	393%	--
R4	12%	12%	81%	559%	12%	11%	353%	--
R1M1	14%	13%	14%	14%	15%	15%	14%	15%
R2M1	13%	13%	14%	14%	14%	15%	14%	15%
R3M1	12%	11%	65%	374%	13%	12%	92%	750%
R4M1	12%	11%	59%	335%	13%	12%	66%	451%
R1M2	14%	13%	14%	14%	14%	14%	14%	14%
R2M2	14%	13%	14%	14%	14%	14%	14%	14%
R3M2	12%	11%	66%	378%	12%	11%	173%	2255%
R4M2	12%	11%	66%	387%	12%	11%	196%	2514%
R1VR1	14%	14%	15%	15%	17%	17%	17%	17%
R2VR2	14%	13%	14%	14%	15%	15%	14%	15%
R3VR3	12%	12%	63%	--	17%	29%	23%	602%
R4VR4	12%	14%	59%	--	16%	23%	21%	295%
R2VR3	13%	13%	15%	15%	14%	15%	18%	18%
R3VR4	12%	13%	55%	--	17%	30%	23%	409%
R1F1	14%	13%	14%	14%	17%	17%	17%	17%
R1F2	14%	13%	14%	14%	16%	16%	16%	16%
R4F1	12%	14%	43%	1553%	14%	12%	17%	90%
R4F2	12%	16%	51%	730%	13%	11%	24%	--

Appendix E-16 Relative error of F_{ST} and results of the hypothesis test to determine if the estimated value of F_{ST} is within 10% of the true value of F_{ST} (sample size = 300).

Age Sample Size = 300
Relative error of F_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-2%	-2%	-2%	-2%	-1%	-2%	-2%	-2%
R1	-6%	-6%	-6%	-6%	-34%	-35%	-35%	-35%
R2	-7%	-7%	-7%	-7%	-36%	-36%	-37%	-37%
R3	6%	16%	-93%	-100%	-1%	7%	-100%	-100%
R4	5%	13%	-93%	-100%	-4%	3%	-100%	-100%
R1M1	-3%	-2%	-3%	-2%	-19%	-19%	-20%	-19%
R2M1	1%	1%	1%	1%	-13%	-13%	-13%	-13%
R3M1	6%	17%	-91%	-100%	3%	8%	-95%	-100%
R4M1	8%	18%	-90%	-99%	8%	9%	-91%	-100%
R1M2	-3%	-2%	-3%	-2%	-15%	-16%	-16%	-16%
R2M2	-3%	-2%	-3%	-2%	-16%	-17%	-17%	-16%
R3M2	6%	17%	-91%	-100%	6%	11%	-99%	-100%
R4M2	6%	16%	-91%	-100%	5%	9%	-99%	-100%
R1VR1	-17%	-17%	-17%	-16%	-38%	-38%	-38%	-39%
R2VR2	-3%	-3%	-3%	-3%	-30%	-31%	-31%	-31%
R3VR3	-12%	-26%	-84%	-100%	-53%	-84%	-65%	-100%
R4VR4	-18%	-44%	-84%	-100%	-49%	-78%	-60%	-99%
R2VR3	6%	-11%	-20%	-7%	-22%	-42%	-47%	-50%
R3VR4	-18%	-38%	-82%	-100%	-55%	-85%	-63%	-100%
R1F1	-4%	-4%	-5%	-4%	-24%	-25%	-25%	-25%
R1F2	-4%	-4%	-4%	-4%	-32%	-32%	-33%	-33%
R4F1	-5%	217%	-85%	-100%	-20%	-5%	-38%	-93%
R4F2	1%	281%	-88%	-100%	-16%	16%	-66%	-100%

Results of testing Ho: The relative difference between the true and estimated F_{ST} is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R4M2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject

Appendix E-17 Average and coefficient of variation (CV) of F_{ST} across 1000 replicates by reader type(s)/scenarios (sample size = 900).

Age Sample Size = 900
Estimated value of F_{ST} among reader(s)/scenarios.
True value of F_{ST} is 0.402

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.397	0.398	0.399	0.400	0.398	0.398	0.398	0.400
R1	0.379	0.381	0.382	0.383	0.264	0.264	0.264	0.265
R2	0.376	0.377	0.378	0.380	0.257	0.258	0.257	0.258
R3	0.431	0.471	0.028	0.000	0.402	0.440	0.001	0.000
R4	0.428	0.461	0.026	0.000	0.392	0.424	0.001	0.000
R1M1	0.395	0.396	0.397	0.398	0.329	0.330	0.329	0.331
R2M1	0.408	0.410	0.410	0.412	0.354	0.355	0.355	0.357
R3M1	0.432	0.477	0.036	0.001	0.419	0.447	0.023	0.000
R4M1	0.442	0.481	0.041	0.002	0.438	0.451	0.036	0.001
R1M2	0.395	0.396	0.397	0.399	0.342	0.343	0.342	0.345
R2M2	0.395	0.396	0.397	0.398	0.338	0.339	0.339	0.340
R3M2	0.432	0.477	0.035	0.001	0.430	0.458	0.006	0.000
R4M2	0.432	0.474	0.035	0.001	0.426	0.449	0.005	0.000
R1VR1	0.338	0.338	0.339	0.340	0.251	0.252	0.251	0.253
R2VR2	0.393	0.394	0.395	0.396	0.280	0.280	0.280	0.281
R3VR3	0.358	0.299	0.066	0.000	0.188	0.068	0.146	0.000
R4VR4	0.332	0.228	0.055	0.000	0.205	0.092	0.165	0.002
R2VR3	0.428	0.360	0.328	0.379	0.314	0.237	0.215	0.205
R3VR4	0.336	0.252	0.074	0.000	0.183	0.062	0.152	0.000
R1F1	0.388	0.389	0.389	0.391	0.307	0.307	0.307	0.308
R1F2	0.388	0.389	0.390	0.392	0.274	0.274	0.274	0.276
R4F1	0.388	1.292	0.054	0.000	0.324	0.389	0.251	0.029
R4F2	0.409	1.559	0.043	0.000	0.340	0.471	0.139	0.000

Estimated value of the CV of F_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	11%	11%	11%	11%	11%	11%	11%	11%
R1	11%	11%	11%	11%	13%	13%	13%	12%
R2	11%	11%	11%	11%	13%	13%	13%	12%
R3	10%	10%	67%	767%	10%	10%	420%	--
R4	10%	11%	69%	807%	10%	10%	449%	--
R1M1	11%	11%	11%	11%	12%	12%	12%	12%
R2M1	11%	11%	11%	11%	12%	12%	12%	11%
R3M1	10%	11%	55%	449%	10%	11%	79%	1624%
R4M1	10%	11%	51%	366%	10%	11%	58%	595%
R1M2	11%	11%	11%	11%	12%	12%	11%	11%
R2M2	11%	11%	11%	11%	12%	12%	12%	11%
R3M2	10%	11%	56%	502%	10%	11%	160%	--
R4M2	10%	11%	57%	488%	10%	11%	174%	--
R1VR1	11%	12%	12%	12%	14%	14%	14%	14%
R2VR2	11%	11%	11%	11%	12%	13%	12%	12%
R3VR3	10%	11%	44%	--	14%	25%	19%	1061%
R4VR4	10%	12%	50%	--	13%	20%	18%	316%
R2VR3	11%	11%	12%	11%	11%	13%	15%	14%
R3VR4	10%	12%	40%	--	14%	27%	19%	535%
R1F1	11%	11%	11%	11%	13%	13%	13%	13%
R1F2	11%	11%	11%	11%	13%	13%	13%	13%
R4F1	10%	13%	50%	--	11%	11%	14%	72%
R4F2	10%	14%	57%	--	11%	10%	21%	--

Appendix E-18 Relative error of F_{ST} and results of the hypothesis test to determine if the estimated value of F_{ST} is within 10% of the true value of F_{ST} (sample size = 900).

Age Sample Size = 900
Estimated expected relative error of F_{ST} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-1%	-1%	-1%	0%	-1%	-1%	-1%	-1%
R1	-6%	-5%	-5%	-5%	-34%	-34%	-34%	-34%
R2	-7%	-6%	-6%	-5%	-36%	-36%	-36%	-36%
R3	7%	17%	-93%	-100%	0%	9%	-100%	-100%
R4	6%	15%	-93%	-100%	-2%	6%	-100%	-100%
R1M1	-2%	-1%	-1%	-1%	-18%	-18%	-18%	-18%
R2M1	2%	2%	2%	2%	-12%	-12%	-12%	-11%
R3M1	7%	19%	-91%	-100%	4%	11%	-94%	-100%
R4M1	10%	20%	-90%	-100%	9%	12%	-91%	-100%
R1M2	-2%	-1%	-1%	-1%	-15%	-15%	-15%	-14%
R2M2	-2%	-2%	-1%	-1%	-16%	-16%	-16%	-15%
R3M2	8%	19%	-91%	-100%	7%	14%	-98%	-100%
R4M2	7%	18%	-91%	-100%	6%	12%	-99%	-100%
R1VR1	-16%	-16%	-16%	-15%	-38%	-37%	-38%	-37%
R2VR2	-2%	-2%	-2%	-1%	-30%	-30%	-30%	-30%
R3VR3	-11%	-26%	-84%	-100%	-53%	-83%	-64%	-100%
R4VR4	-17%	-43%	-86%	-100%	-49%	-77%	-59%	-100%
R2VR3	6%	-10%	-18%	-6%	-22%	-41%	-46%	-49%
R3VR4	-16%	-37%	-82%	-100%	-54%	-84%	-62%	-100%
R1F1	-4%	-3%	-3%	-3%	-24%	-24%	-24%	-23%
R1F2	-3%	-3%	-3%	-3%	-32%	-32%	-32%	-31%
R4F1	-4%	221%	-87%	-100%	-19%	-3%	-37%	-93%
R4F2	2%	288%	-89%	-100%	-16%	17%	-65%	-100%

Results of testing Ho: The relative difference between the true and estimated F_{ST} is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R4M1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R4M2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R1VR1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject

Appendix E-19 Average and coefficient of variation (CV) of F_{m+} across 1000 replicates by reader type(s)/scenarios (sample size = 100).

Age Sample Size = 100
Estimated value of F_{m+} among reader(s)/scenarios.
True value of F_{m+} is 0.212

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
R1	0.210	0.210	0.210	0.210	0.204	0.204	0.204	0.204
R2	0.210	0.210	0.210	0.210	0.203	0.203	0.204	0.203
R3	0.172	0.143	0.222	0.294	0.176	0.146	0.221	0.293
R4	0.172	0.142	0.221	0.293	0.176	0.145	0.221	0.293
R1M1	0.212	0.212	0.212	0.212	0.205	0.205	0.205	0.205
R2M1	0.212	0.211	0.212	0.212	0.205	0.204	0.205	0.205
R3M1	0.171	0.142	0.224	0.300	0.172	0.142	0.221	0.293
R4M1	0.171	0.142	0.224	0.298	0.172	0.140	0.221	0.293
R1M2	0.212	0.212	0.212	0.212	0.209	0.209	0.209	0.208
R2M2	0.212	0.212	0.212	0.212	0.208	0.208	0.208	0.208
R3M2	0.171	0.142	0.224	0.300	0.175	0.144	0.221	0.293
R4M2	0.171	0.142	0.224	0.298	0.175	0.144	0.221	0.293
R1VR1	0.213	0.213	0.213	0.213	0.214	0.214	0.214	0.214
R2VR2	0.211	0.211	0.211	0.212	0.205	0.204	0.205	0.204
R3VR3	0.172	0.135	0.219	0.220	0.179	0.128	0.210	0.206
R4VR4	0.172	0.130	0.221	0.221	0.178	0.131	0.210	0.207
R2VR3	0.208	0.208	0.212	0.210	0.197	0.192	0.211	0.206
R3VR4	0.172	0.132	0.220	0.219	0.179	0.128	0.210	0.206
R1F1	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
R1F2	0.212	0.212	0.212	0.212	0.215	0.215	0.215	0.215
R4F1	0.171	0.202	0.221	0.248	0.187	0.190	0.212	0.209
R4F2	0.171	0.203	0.222	0.281	0.188	0.193	0.214	0.211

Estimated value of the CV of F_{m+} among reader(s)/scenarios.

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	1.3%	1.2%	1.2%	1.3%	1.2%	1.2%	1.2%	1.3%
R1	0.8%	0.9%	0.9%	0.9%	1.0%	1.0%	1.0%	1.1%
R2	0.8%	0.8%	0.8%	0.8%	1.1%	1.0%	1.1%	1.1%
R3	2.3%	3.7%	2.7%	4.5%	2.2%	3.7%	0.0%	0.0%
R4	2.4%	3.7%	1.8%	3.4%	2.2%	3.6%	0.0%	0.0%
R1M1	1.2%	1.2%	1.1%	1.2%	1.1%	1.1%	1.1%	1.1%
R2M1	1.1%	1.0%	1.1%	1.1%	1.1%	1.1%	1.1%	1.1%
R3M1	2.4%	3.7%	6.3%	11.3%	2.6%	4.2%	0.0%	0.0%
R4M1	2.4%	3.7%	5.8%	9.7%	2.6%	4.4%	0.0%	0.0%
R1M2	1.2%	1.2%	1.1%	1.2%	0.9%	0.8%	0.8%	0.9%
R2M2	1.1%	1.0%	1.1%	1.1%	0.8%	0.8%	0.8%	0.8%
R3M2	2.4%	3.7%	6.3%	11.3%	2.2%	3.7%	0.0%	0.0%
R4M2	2.4%	3.7%	5.8%	9.7%	2.2%	3.8%	0.0%	0.0%
R1VR1	1.3%	1.3%	1.2%	1.3%	0.7%	0.7%	0.8%	0.7%
R2VR2	1.0%	1.1%	1.0%	1.1%	1.0%	1.0%	1.0%	1.1%
R3VR3	2.3%	3.9%	0.8%	5.4%	2.1%	4.1%	0.8%	1.1%
R4VR4	2.4%	4.3%	0.4%	1.9%	2.1%	4.1%	0.8%	1.1%
R2VR3	0.8%	0.9%	1.2%	0.9%	1.3%	1.5%	0.8%	1.0%
R3VR4	2.3%	4.1%	0.8%	4.2%	2.0%	4.1%	0.8%	1.1%
R1F1	1.3%	1.3%	1.3%	1.3%	1.6%	1.6%	1.5%	1.5%
R1F2	1.3%	1.2%	1.2%	1.3%	1.0%	1.0%	1.0%	0.9%
R4F1	2.4%	1.0%	1.4%	14.6%	1.9%	1.7%	0.8%	1.1%
R4F2	2.4%	0.9%	3.2%	12.7%	1.7%	1.5%	0.7%	1.1%

Appendix E-20 Relative error of F_{m+} and results of the hypothesis test to determine if the estimated value of F_{m+} is within 10% of the true value of F_{m+} (sample size = 100).

Age Sample Size = 100
Relative error of F_{m+} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0%	0%	0%	0%	0%	0%	0%	0%
R1	-1%	-1%	-1%	-1%	-4%	-4%	-4%	-4%
R2	-1%	-1%	-1%	-1%	-4%	-4%	-4%	-4%
R3	-19%	-33%	5%	39%	-17%	-31%	4%	38%
R4	-19%	-33%	4%	38%	-17%	-32%	4%	38%
R1M1	0%	0%	0%	0%	-3%	-3%	-3%	-3%
R2M1	0%	0%	0%	0%	-4%	-4%	-3%	-4%
R3M1	-19%	-33%	6%	42%	-19%	-33%	4%	38%
R4M1	-19%	-33%	5%	41%	-19%	-34%	4%	38%
R1M2	0%	0%	0%	0%	-2%	-2%	-2%	-2%
R2M2	0%	0%	0%	0%	-2%	-2%	-2%	-2%
R3M2	-19%	-33%	6%	42%	-17%	-32%	4%	38%
R4M2	-19%	-33%	5%	41%	-17%	-32%	4%	38%
R1VR1	0%	0%	0%	0%	1%	1%	1%	1%
R2VR2	0%	0%	0%	0%	-4%	-4%	-3%	-4%
R3VR3	-19%	-36%	4%	4%	-15%	-39%	-1%	-3%
R4VR4	-19%	-39%	4%	4%	-16%	-38%	-1%	-2%
R2VR3	-2%	-2%	0%	-1%	-7%	-9%	-1%	-3%
R3VR4	-19%	-38%	4%	3%	-15%	-40%	-1%	-3%
R1F1	0%	0%	0%	0%	0%	0%	0%	0%
R1F2	0%	0%	0%	0%	2%	2%	2%	2%
R4F1	-19%	-5%	4%	17%	-12%	-10%	0%	-1%
R4F2	-19%	-4%	5%	33%	-11%	-9%	1%	0%

Results of testing Ho: The relative difference between the true and estimated F_{m+} is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4M1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4M2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R4VR4	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR4	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R4F1	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject
R4F2	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Fail to Reject

Appendix E-21 Average and coefficient of variation (CV) of F_{m+} across 1000 replicates by reader type(s)/scenarios (sample size = 300).

Age Sample Size = 300
Estimated value of F_{m+} among reader(s)/scenarios.
True value of F_{m+} is 0.212

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
R1	0.210	0.210	0.210	0.210	0.204	0.204	0.204	0.204
R2	0.210	0.210	0.210	0.210	0.204	0.204	0.204	0.204
R3	0.172	0.143	0.221	0.293	0.176	0.146	0.221	0.293
R4	0.172	0.143	0.221	0.293	0.176	0.145	0.221	0.293
R1M1	0.211	0.211	0.211	0.211	0.205	0.205	0.205	0.205
R2M1	0.211	0.211	0.211	0.211	0.205	0.205	0.205	0.205
R3M1	0.171	0.143	0.221	0.293	0.172	0.142	0.221	0.293
R4M1	0.171	0.142	0.221	0.293	0.172	0.141	0.221	0.293
R1M2	0.212	0.212	0.212	0.212	0.209	0.209	0.209	0.209
R2M2	0.211	0.211	0.211	0.211	0.208	0.208	0.208	0.208
R3M2	0.171	0.143	0.221	0.293	0.175	0.144	0.221	0.293
R4M2	0.171	0.143	0.221	0.293	0.175	0.144	0.221	0.293
R1VR1	0.212	0.212	0.212	0.212	0.214	0.214	0.214	0.214
R2VR2	0.211	0.211	0.211	0.211	0.205	0.205	0.205	0.205
R3VR3	0.172	0.136	0.218	0.216	0.179	0.128	0.210	0.206
R4VR4	0.172	0.130	0.220	0.218	0.178	0.130	0.210	0.207
R2VR3	0.208	0.208	0.212	0.210	0.197	0.192	0.211	0.206
R3VR4	0.172	0.132	0.218	0.216	0.179	0.128	0.210	0.207
R1F1	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
R1F2	0.212	0.212	0.212	0.212	0.215	0.215	0.215	0.215
R4F1	0.171	0.202	0.221	0.222	0.187	0.190	0.212	0.209
R4F2	0.171	0.203	0.221	0.230	0.188	0.193	0.214	0.211

Estimated value of the CV of F_{m+} among reader(s)/scenarios.

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
R1	0.4%	0.4%	0.4%	0.4%	0.7%	0.6%	0.6%	0.6%
R2	0.5%	0.4%	0.5%	0.5%	0.6%	0.6%	0.7%	0.6%
R3	1.6%	2.7%	0.0%	0.0%	1.5%	2.5%	0.0%	0.0%
R4	1.5%	2.8%	0.0%	0.0%	1.4%	2.4%	0.0%	0.0%
R1M1	0.4%	0.4%	0.4%	0.4%	0.6%	0.7%	0.7%	0.7%
R2M1	0.4%	0.4%	0.4%	0.4%	0.7%	0.7%	0.7%	0.7%
R3M1	1.6%	2.8%	0.0%	0.0%	1.7%	2.8%	0.0%	0.0%
R4M1	1.6%	2.8%	0.0%	0.0%	1.7%	2.9%	0.0%	0.0%
R1M2	0.4%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%	0.5%
R2M2	0.4%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%	0.5%
R3M2	1.6%	2.8%	0.0%	0.0%	1.5%	2.6%	0.0%	0.0%
R4M2	1.6%	2.8%	0.0%	0.0%	1.4%	2.6%	0.0%	0.0%
R1VR1	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%
R2VR2	0.4%	0.4%	0.4%	0.4%	0.6%	0.6%	0.6%	0.6%
R3VR3	1.6%	2.9%	0.3%	0.5%	1.3%	2.8%	0.5%	0.7%
R4VR4	1.5%	3.2%	0.4%	0.6%	1.3%	2.7%	0.5%	0.6%
R2VR3	0.5%	0.5%	0.4%	0.4%	0.8%	0.9%	0.5%	0.6%
R3VR4	1.6%	3.0%	0.2%	0.5%	1.3%	2.8%	0.5%	0.7%
R1F1	0.4%	0.4%	0.4%	0.4%	0.5%	0.5%	0.5%	0.5%
R1F2	0.4%	0.4%	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%
R4F1	1.6%	0.6%	0.0%	3.7%	1.2%	1.0%	0.5%	0.6%
R4F2	1.6%	0.6%	0.0%	10.4%	1.0%	0.9%	0.4%	0.5%

Appendix E-22 Relative error of F_{m+} and results of the hypothesis test to determine if the estimated value of F_{m+} is within 10% of the true value of F_{m+} (sample size = 300).

Age Sample Size = 300

Relative error of F_{m+} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0%	0%	0%	0%	0%	0%	0%	0%
R1	-1%	-1%	-1%	-1%	-4%	-4%	-4%	-4%
R2	-1%	-1%	-1%	-1%	-4%	-4%	-4%	-4%
R3	-19%	-32%	4%	38%	-17%	-31%	4%	38%
R4	-19%	-33%	4%	38%	-17%	-31%	4%	38%
R1M1	0%	0%	0%	0%	-3%	-3%	-3%	-3%
R2M1	0%	0%	0%	0%	-3%	-3%	-3%	-3%
R3M1	-19%	-33%	4%	38%	-19%	-33%	4%	38%
R4M1	-19%	-33%	4%	38%	-19%	-34%	4%	38%
R1M2	0%	0%	0%	0%	-2%	-2%	-2%	-2%
R2M2	0%	0%	0%	0%	-2%	-2%	-2%	-2%
R3M2	-19%	-33%	4%	38%	-17%	-32%	4%	38%
R4M2	-19%	-33%	4%	38%	-17%	-32%	4%	38%
R1VR1	0%	0%	0%	0%	1%	1%	1%	1%
R2VR2	0%	0%	0%	0%	-3%	-3%	-3%	-3%
R3VR3	-19%	-36%	3%	2%	-15%	-40%	-1%	-3%
R4VR4	-19%	-39%	4%	3%	-16%	-39%	-1%	-2%
R2VR3	-2%	-2%	0%	-1%	-7%	-9%	-1%	-3%
R3VR4	-19%	-38%	3%	2%	-15%	-40%	-1%	-3%
R1F1	0%	0%	0%	0%	0%	0%	0%	0%
R1F2	0%	0%	0%	0%	1%	1%	1%	1%
R4F1	-19%	-5%	4%	5%	-12%	-10%	0%	-1%
R4F2	-19%	-4%	4%	9%	-11%	-9%	1%	0%

Results of testing Ho: The relative difference between the true and estimated F_{m+} is less than the differential.

Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4M1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4M2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R4VR4	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR4	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R4F1	Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R4F2	Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Fail to Reject	Fail to Reject	Fail to Reject

Appendix E-23 Average and coefficient of variation (CV) of F_{m+} across 1000 replicates by reader type(s)/scenarios (sample size = 900).

Age Sample Size = 900
Estimated value of F_{m+} among reader(s)/scenarios.
True value of F_{m+} is 0.212

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
R1	0.210	0.210	0.210	0.210	0.204	0.204	0.204	0.204
R2	0.210	0.210	0.210	0.210	0.204	0.204	0.204	0.204
R3	0.172	0.143	0.221	0.293	0.176	0.146	0.221	0.293
R4	0.172	0.143	0.221	0.293	0.176	0.146	0.221	0.293
R1M1	0.211	0.212	0.212	0.212	0.205	0.205	0.205	0.205
R2M1	0.211	0.211	0.211	0.211	0.205	0.205	0.205	0.205
R3M1	0.171	0.143	0.221	0.293	0.172	0.143	0.221	0.293
R4M1	0.171	0.143	0.221	0.293	0.172	0.141	0.221	0.293
R1M2	0.212	0.212	0.212	0.212	0.209	0.209	0.209	0.209
R2M2	0.211	0.211	0.212	0.211	0.209	0.209	0.209	0.209
R3M2	0.171	0.143	0.221	0.293	0.175	0.145	0.221	0.293
R4M2	0.171	0.143	0.221	0.293	0.175	0.144	0.221	0.293
R1VR1	0.212	0.212	0.212	0.212	0.214	0.214	0.214	0.214
R2VR2	0.211	0.211	0.211	0.211	0.205	0.205	0.205	0.205
R3VR3	0.172	0.135	0.218	0.216	0.179	0.128	0.210	0.206
R4VR4	0.172	0.130	0.219	0.218	0.178	0.130	0.210	0.207
R2VR3	0.208	0.208	0.212	0.210	0.197	0.192	0.211	0.206
R3VR4	0.172	0.132	0.218	0.216	0.179	0.127	0.210	0.207
R1F1	0.212	0.212	0.212	0.212	0.212	0.212	0.212	0.212
R1F2	0.212	0.212	0.212	0.212	0.215	0.215	0.215	0.215
R4F1	0.171	0.202	0.221	0.221	0.187	0.190	0.212	0.209
R4F2	0.171	0.203	0.221	0.221	0.188	0.193	0.215	0.211

Estimated value of the CV of F_{m+} among reader(s)/scenarios.

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
R1	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%
R2	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%
R3	1.1%	2.4%	0.0%	0.0%	1.0%	2.2%	0.0%	0.0%
R4	1.1%	2.4%	0.0%	0.0%	1.0%	2.1%	0.0%	0.0%
R1M1	0.2%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%
R2M1	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%
R3M1	1.2%	2.4%	0.0%	0.0%	1.2%	2.4%	0.0%	0.0%
R4M1	1.2%	2.4%	0.0%	0.0%	1.2%	2.5%	0.0%	0.0%
R1M2	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.0%	0.0%
R2M2	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
R3M2	1.2%	2.4%	0.0%	0.0%	1.0%	2.3%	0.0%	0.0%
R4M2	1.2%	2.4%	0.0%	0.0%	1.0%	2.3%	0.0%	0.0%
R1VR1	0.2%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
R2VR2	0.3%	0.3%	0.3%	0.3%	0.4%	0.4%	0.4%	0.4%
R3VR3	1.1%	2.5%	0.1%	0.3%	0.9%	2.4%	0.3%	0.4%
R4VR4	1.1%	2.5%	0.1%	0.2%	0.9%	2.3%	0.3%	0.4%
R2VR3	0.3%	0.3%	0.3%	0.3%	0.5%	0.6%	0.3%	0.4%
R3VR4	1.1%	2.5%	0.1%	0.3%	0.9%	2.4%	0.3%	0.4%
R1F1	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.4%
R1F2	0.2%	0.3%	0.3%	0.3%	0.2%	0.2%	0.2%	0.2%
R4F1	1.1%	0.4%	0.1%	0.1%	0.8%	0.7%	0.3%	0.4%
R4F2	1.1%	0.4%	0.1%	0.2%	0.7%	0.6%	0.2%	0.3%

Appendix E-24 Relative error of F_{m+} and results of the hypothesis test to determine if the estimated value of F_{m+} is within 10% of the true value of F_{m+} (sample size = 900).

Age Sample Size = 900
Relative error of F_{m+} among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0%	0%	0%	0%	0%	0%	0%	0%
R1	-1%	-1%	-1%	-1%	-4%	-4%	-4%	-4%
R2	-1%	-1%	-1%	-1%	-4%	-4%	-4%	-4%
R3	-19%	-32%	4%	38%	-17%	-31%	4%	38%
R4	-19%	-33%	4%	38%	-17%	-31%	4%	38%
R1M1	0%	0%	0%	0%	-3%	-3%	-3%	-3%
R2M1	0%	0%	0%	0%	-3%	-3%	-3%	-3%
R3M1	-19%	-33%	4%	38%	-19%	-33%	4%	38%
R4M1	-19%	-33%	4%	38%	-19%	-33%	4%	38%
R1M2	0%	0%	0%	0%	-2%	-2%	-2%	-2%
R2M2	0%	0%	0%	0%	-2%	-2%	-2%	-2%
R3M2	-19%	-33%	4%	38%	-17%	-32%	4%	38%
R4M2	-19%	-33%	4%	38%	-17%	-32%	4%	38%
R1VR1	0%	0%	0%	0%	1%	1%	1%	1%
R2VR2	0%	0%	0%	0%	-3%	-3%	-3%	-3%
R3VR3	-19%	-36%	3%	2%	-15%	-40%	-1%	-3%
R4VR4	-19%	-39%	3%	3%	-16%	-39%	-1%	-2%
R2VR3	-2%	-2%	0%	-1%	-7%	-9%	-1%	-3%
R3VR4	-19%	-38%	3%	2%	-15%	-40%	-1%	-3%
R1F1	0%	0%	0%	0%	0%	0%	0%	0%
R1F2	0%	0%	0%	0%	1%	1%	1%	1%
R4F1	-19%	-5%	4%	4%	-12%	-10%	0%	-1%
R4F2	-19%	-4%	4%	4%	-11%	-9%	1%	0%

Results of testing Ho: The relative difference between the true and estimated F_{m+} is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4M1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4M2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R4VR4	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR4	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R4F1	Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R4F2	Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Fail to Reject	Fail to Reject	Fail to Reject

Appendix E-25 Average and coefficient of variation (CV) of projected abundance across 1000 replicates by reader type(s)/scenarios (sample size = 100).

Age Sample Size = 100
Estimated value of projected abundance among reader(s)/scenarios.
True value of projected abundance is 153,133

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	146,515	147,363	147,237	146,126	147,491	146,294	146,386	147,134
R1	145,497	146,663	146,472	145,369	125,268	124,565	124,116	124,890
R2	145,686	147,132	146,212	145,302	123,536	122,446	123,579	123,529
R3	121,364	88,638	60,267	58,936	120,776	87,764	56,936	55,608
R4	120,898	86,667	59,859	58,565	118,554	84,949	57,055	55,586
R1M1	146,498	147,281	146,765	145,972	135,666	135,615	134,553	136,280
R2M1	149,166	150,257	149,842	148,982	140,507	139,179	140,091	140,660
R3M1	120,937	88,836	63,783	63,011	118,495	83,713	60,384	59,181
R4M1	122,682	88,604	63,692	62,466	120,297	82,380	62,009	60,656
R1M2	146,565	147,457	147,114	146,217	143,382	143,356	142,302	143,560
R2M2	146,747	147,792	147,408	146,574	143,062	141,403	142,038	142,402
R3M2	121,139	89,001	63,734	62,953	124,753	88,242	57,375	55,879
R4M2	121,147	88,240	63,036	62,063	123,916	86,959	57,253	55,636
R1VR1	135,073	135,864	135,446	134,835	126,934	126,248	125,427	126,373
R2VR2	145,975	147,305	147,157	146,045	128,301	127,219	127,449	128,173
R3VR3	110,074	61,386	79,312	38,691	88,400	35,512	107,023	71,808
R4VR4	106,014	50,186	72,466	38,373	90,610	39,203	110,317	74,952
R2VR3	156,825	143,201	133,272	144,522	128,926	108,139	118,871	113,400
R3VR4	106,088	53,978	81,658	39,791	87,677	35,069	107,619	73,205
R1F1	144,374	145,126	144,982	144,053	128,765	127,962	128,412	129,599
R1F2	144,757	145,456	145,333	144,457	126,732	125,887	126,042	127,089
R4F1	114,392	280,569	63,348	43,456	120,460	130,387	126,991	83,248
R4F2	118,128	311,005	62,486	55,993	125,313	149,439	103,032	61,078

Estimated value of the CV of projected abundance among reader(s)/scenarios.

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	20%	19%	19%	19%	19%	19%	20%	19%
R1	20%	20%	20%	19%	19%	19%	20%	20%
R2	20%	20%	20%	20%	20%	19%	20%	20%
R3	20%	21%	20%	22%	19%	22%	15%	15%
R4	20%	21%	16%	17%	19%	21%	15%	15%
R1M1	20%	19%	19%	19%	20%	21%	21%	21%
R2M1	20%	20%	19%	19%	21%	20%	21%	21%
R3M1	20%	21%	33%	37%	20%	23%	15%	15%
R4M1	20%	21%	31%	34%	20%	23%	16%	16%
R1M2	20%	19%	19%	19%	20%	20%	21%	20%
R2M2	20%	20%	19%	19%	20%	19%	21%	21%
R3M2	20%	21%	33%	37%	19%	22%	15%	15%
R4M2	20%	21%	30%	35%	19%	22%	15%	15%
R1VR1	20%	19%	19%	19%	22%	22%	21%	21%
R2VR2	20%	20%	20%	19%	19%	19%	20%	20%
R3VR3	20%	22%	29%	23%	18%	20%	21%	19%
R4VR4	20%	22%	21%	17%	18%	20%	21%	20%
R2VR3	21%	20%	19%	19%	19%	19%	21%	19%
R3VR4	20%	22%	31%	22%	18%	21%	21%	20%
R1F1	20%	19%	19%	19%	21%	21%	22%	21%
R1F2	20%	19%	19%	19%	20%	21%	21%	20%
R4F1	20%	22%	17%	40%	20%	20%	23%	21%
R4F2	20%	21%	21%	36%	19%	20%	21%	19%

Appendix E-26 Relative error of projected abundance and results of the hypothesis test to determine if the estimated value of projected abundance is within 10% of the true value of projected abundance (sample size = 100).

Age Sample Size = 100
Relative error of projected abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-4%	-4%	-4%	-5%	-4%	-4%	-4%	-4%
R1	-5%	-4%	-4%	-5%	-18%	-19%	-19%	-18%
R2	-5%	-4%	-5%	-5%	-19%	-20%	-19%	-19%
R3	-21%	-42%	-61%	-62%	-21%	-43%	-63%	-64%
R4	-21%	-43%	-61%	-62%	-23%	-45%	-63%	-64%
R1M1	-4%	-4%	-4%	-5%	-11%	-11%	-12%	-11%
R2M1	-3%	-2%	-2%	-3%	-8%	-9%	-9%	-8%
R3M1	-21%	-42%	-58%	-59%	-23%	-45%	-61%	-61%
R4M1	-20%	-42%	-58%	-59%	-21%	-46%	-60%	-60%
R1M2	-4%	-4%	-4%	-5%	-6%	-6%	-7%	-6%
R2M2	-4%	-3%	-4%	-4%	-7%	-8%	-7%	-7%
R3M2	-21%	-42%	-58%	-59%	-19%	-42%	-63%	-64%
R4M2	-21%	-42%	-59%	-59%	-19%	-43%	-63%	-64%
R1VR1	-12%	-11%	-12%	-12%	-17%	-18%	-18%	-17%
R2VR2	-5%	-4%	-4%	-5%	-16%	-17%	-17%	-16%
R3VR3	-28%	-60%	-48%	-75%	-42%	-77%	-30%	-53%
R4VR4	-31%	-67%	-53%	-75%	-41%	-74%	-28%	-51%
R2VR3	2%	-6%	-13%	-6%	-16%	-29%	-22%	-26%
R3VR4	-31%	-65%	-47%	-74%	-43%	-77%	-30%	-52%
R1F1	-6%	-5%	-5%	-6%	-16%	-16%	-16%	-15%
R1F2	-5%	-5%	-5%	-6%	-17%	-18%	-18%	-17%
R4F1	-25%	83%	-59%	-72%	-21%	-15%	-17%	-46%
R4F2	-23%	103%	-59%	-63%	-18%	-2%	-33%	-60%

Results of testing Ho: The relative difference between the true and estimated projected abundance is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4F2	Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject

Appendix E-27 Average and coefficient of variation (CV) of projected abundance across 1000 replicates by reader type(s)/scenarios (sample size = 300).

Age Sample Size = 300
Estimated value of projected abundance among reader(s)/scenarios.
True value of projected abundance is 153,133

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	148,937	149,256	147,636	148,229	149,192	147,102	147,699	147,206
R1	148,508	149,001	147,243	148,018	126,731	125,259	125,413	124,980
R2	148,553	148,697	147,130	147,786	124,641	123,533	123,798	123,107
R3	123,982	91,713	59,870	58,202	122,624	88,809	57,282	54,917
R4	123,427	89,755	59,923	58,254	119,710	85,797	57,353	55,104
R1M1	148,966	149,244	147,539	148,250	138,251	136,683	136,974	136,352
R2M1	151,803	152,385	150,487	151,042	143,230	141,573	141,948	141,894
R3M1	123,478	91,992	60,221	58,764	120,576	84,854	60,869	58,492
R4M1	125,234	91,696	60,760	59,258	123,936	83,515	62,579	60,192
R1M2	149,031	149,424	147,726	148,471	145,517	143,960	144,337	143,629
R2M2	149,194	149,705	147,864	148,503	144,649	143,043	143,331	143,330
R3M2	123,656	92,080	60,174	58,681	126,821	89,146	57,828	55,271
R4M2	123,646	91,318	60,161	58,704	126,368	87,428	57,652	55,135
R1VR1	137,221	137,580	135,874	136,583	127,847	126,970	127,120	126,383
R2VR2	149,016	149,471	147,805	148,376	129,864	128,151	128,692	127,990
R3VR3	112,313	62,747	93,778	41,864	89,304	34,845	107,702	71,085
R4VR4	107,607	50,824	82,928	40,093	91,613	38,624	111,338	74,014
R2VR3	159,962	145,121	133,863	147,057	130,763	108,498	120,008	113,222
R3VR4	108,015	54,946	95,505	43,170	88,163	34,381	109,176	72,414
R1F1	146,871	147,170	145,424	146,148	131,662	130,071	130,372	129,696
R1F2	147,117	147,544	145,872	146,535	128,356	127,100	127,339	126,732
R4F1	116,635	288,941	63,452	32,551	122,449	131,429	128,888	82,345
R4F2	120,564	321,452	61,851	34,843	127,149	150,488	104,294	60,692

Estimated value of the CV of projected abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	17%	16%	17%	18%	16%	17%	16%	16%
R1	17%	16%	17%	18%	16%	16%	16%	17%
R2	17%	16%	17%	17%	16%	16%	16%	16%
R3	18%	18%	14%	15%	17%	18%	14%	14%
R4	18%	18%	14%	15%	17%	18%	14%	14%
R1M1	17%	16%	17%	18%	17%	17%	17%	17%
R2M1	17%	16%	17%	18%	17%	17%	16%	17%
R3M1	18%	18%	14%	15%	18%	19%	14%	14%
R4M1	18%	18%	14%	15%	18%	19%	14%	14%
R1M2	17%	16%	17%	18%	16%	17%	16%	17%
R2M2	17%	16%	17%	18%	16%	17%	16%	17%
R3M2	18%	18%	14%	15%	17%	18%	13%	14%
R4M2	18%	18%	14%	15%	17%	18%	14%	14%
R1VR1	17%	16%	17%	17%	16%	17%	17%	17%
R2VR2	17%	16%	17%	18%	16%	16%	16%	16%
R3VR3	18%	18%	21%	18%	16%	17%	16%	16%
R4VR4	17%	18%	20%	16%	16%	17%	16%	16%
R2VR3	17%	16%	17%	18%	16%	16%	16%	16%
R3VR4	17%	18%	20%	18%	16%	17%	16%	16%
R1F1	17%	16%	17%	18%	18%	18%	17%	17%
R1F2	17%	16%	17%	18%	17%	17%	17%	17%
R4F1	18%	18%	14%	18%	17%	17%	17%	17%
R4F2	18%	18%	14%	32%	16%	16%	16%	16%

Appendix E-28 Relative error of projected abundance and results of the hypothesis test to determine if the estimated value of projected abundance is within 10% of the true value of projected abundance (sample size = 300).

Age Sample Size = 300
Relative error of projected abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-3%	-3%	-4%	-3%	-3%	-4%	-4%	-4%
R1	-3%	-3%	-4%	-3%	-17%	-18%	-18%	-18%
R2	-3%	-3%	-4%	-3%	-19%	-19%	-19%	-20%
R3	-19%	-40%	-61%	-62%	-20%	-42%	-63%	-64%
R4	-19%	-41%	-61%	-62%	-22%	-44%	-63%	-64%
R1M1	-3%	-3%	-4%	-3%	-10%	-11%	-11%	-11%
R2M1	-1%	0%	-2%	-1%	-6%	-8%	-7%	-7%
R3M1	-19%	-40%	-61%	-62%	-21%	-45%	-60%	-62%
R4M1	-18%	-40%	-60%	-61%	-19%	-45%	-59%	-61%
R1M2	-3%	-2%	-4%	-3%	-5%	-6%	-6%	-6%
R2M2	-3%	-2%	-3%	-3%	-6%	-7%	-6%	-6%
R3M2	-19%	-40%	-61%	-62%	-17%	-42%	-62%	-64%
R4M2	-19%	-40%	-61%	-62%	-17%	-43%	-62%	-64%
R1VR1	-10%	-10%	-11%	-11%	-17%	-17%	-17%	-17%
R2VR2	-3%	-2%	-3%	-3%	-15%	-16%	-16%	-16%
R3VR3	-27%	-59%	-39%	-73%	-42%	-77%	-30%	-54%
R4VR4	-30%	-67%	-46%	-74%	-40%	-75%	-27%	-52%
R2VR3	4%	-5%	-13%	-4%	-15%	-29%	-22%	-26%
R3VR4	-29%	-64%	-38%	-72%	-42%	-78%	-29%	-53%
R1F1	-4%	-4%	-5%	-5%	-14%	-15%	-15%	-15%
R1F2	-4%	-4%	-5%	-4%	-16%	-17%	-17%	-17%
R4F1	-24%	89%	-59%	-79%	-20%	-14%	-16%	-46%
R4F2	-21%	110%	-60%	-77%	-17%	-2%	-32%	-21%

Results of testing Ho: The relative difference between the true and estimated projected abundance is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4F2	Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject

Appendix E-29 Average and coefficient of variation (CV) of projected abundance across 1000 replicates by reader type(s)/scenarios (sample size = 900).

Age Sample Size = 900
Estimated value of projected abundance among reader(s)/scenarios.
True value of projected abundance is 153,133

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	149,262	149,877	148,995	150,903	150,056	149,076	148,633	150,060
R1	148,858	149,476	148,719	150,509	127,059	126,287	125,955	126,849
R2	148,460	148,986	148,486	150,450	125,310	124,580	124,153	125,193
R3	124,965	92,290	60,009	59,000	123,226	90,985	57,381	55,534
R4	124,380	90,382	60,027	59,047	120,971	88,147	57,367	55,584
R1M1	149,276	149,843	148,996	150,880	139,030	138,311	137,579	139,053
R2M1	152,272	152,782	151,954	153,889	144,151	143,361	143,019	144,362
R3M1	124,266	92,540	60,355	59,601	121,930	87,576	61,079	59,168
R4M1	126,063	92,520	60,855	60,120	124,816	86,144	62,697	60,849
R1M2	149,449	149,986	149,200	151,129	146,153	145,538	144,841	146,376
R2M2	149,694	150,095	149,391	151,239	145,272	144,616	144,271	145,476
R3M2	124,405	92,676	60,301	59,497	127,782	91,566	57,901	55,891
R4M2	124,324	91,982	60,227	59,518	127,155	89,989	57,697	55,705
R1VR1	137,499	137,870	137,205	138,771	128,558	127,969	127,540	128,694
R2VR2	149,340	150,015	149,197	151,075	130,096	129,369	129,133	129,877
R3VR3	112,863	62,787	94,797	42,835	89,348	35,242	108,399	71,630
R4VR4	108,160	50,914	84,722	40,795	91,727	39,098	111,669	75,123
R2VR3	160,244	145,531	135,214	149,592	131,248	109,492	120,207	115,011
R3VR4	108,540	54,909	96,260	43,934	88,494	34,654	109,511	73,073
R1F1	147,200	147,701	146,863	148,638	132,729	131,576	131,479	132,286
R1F2	147,421	148,010	147,277	149,133	129,144	128,205	128,117	129,124
R4F1	117,242	291,316	65,914	32,851	123,017	133,524	129,480	83,651
R4F2	121,164	324,721	63,713	31,657	127,838	152,855	104,946	61,387

Estimated value of the CV of projected abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	15%	16%	16%	16%	17%	16%	16%	16%
R1	15%	16%	16%	16%	16%	16%	16%	15%
R2	15%	16%	16%	16%	16%	16%	15%	15%
R3	16%	19%	14%	14%	17%	18%	14%	14%
R4	16%	19%	14%	14%	17%	18%	14%	14%
R1M1	15%	16%	16%	16%	16%	16%	16%	16%
R2M1	15%	16%	16%	16%	17%	16%	16%	16%
R3M1	16%	19%	14%	14%	17%	19%	14%	14%
R4M1	16%	19%	14%	14%	17%	19%	14%	14%
R1M2	15%	16%	16%	16%	16%	16%	16%	16%
R2M2	15%	16%	16%	16%	16%	16%	16%	15%
R3M2	16%	19%	14%	14%	17%	18%	14%	14%
R4M2	16%	19%	14%	14%	17%	18%	14%	14%
R1VR1	15%	16%	16%	16%	16%	16%	16%	16%
R2VR2	15%	16%	16%	16%	16%	16%	16%	15%
R3VR3	15%	18%	16%	15%	16%	17%	15%	15%
R4VR4	15%	18%	16%	15%	16%	17%	15%	14%
R2VR3	15%	16%	16%	16%	16%	16%	16%	15%
R3VR4	15%	18%	16%	15%	16%	17%	16%	15%
R1F1	15%	16%	16%	16%	17%	16%	16%	16%
R1F2	15%	16%	16%	16%	16%	16%	16%	15%
R4F1	16%	19%	17%	14%	16%	16%	16%	15%
R4F2	16%	19%	16%	14%	16%	16%	16%	15%

Appendix E-30 Relative error of projected abundance and results of the hypothesis test to determine if the estimated value of projected abundance is within 10% of the true value of projected abundance (sample size = 900).

Age Sample Size = 900
Relative error of projected abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-3%	-2%	-3%	-1%	-2%	-3%	-3%	-2%
R1	-3%	-2%	-3%	-2%	-17%	-18%	-18%	-17%
R2	-3%	-3%	-3%	-2%	-18%	-19%	-19%	-18%
R3	-18%	-40%	-61%	-61%	-20%	-41%	-63%	-64%
R4	-19%	-41%	-61%	-61%	-21%	-42%	-63%	-64%
R1M1	-3%	-2%	-3%	-1%	-9%	-10%	-10%	-9%
R2M1	-1%	0%	-1%	0%	-6%	-6%	-7%	-6%
R3M1	-19%	-40%	-61%	-61%	-20%	-43%	-60%	-61%
R4M1	-18%	-40%	-60%	-61%	-18%	-44%	-59%	-60%
R1M2	-2%	-2%	-3%	-1%	-5%	-5%	-5%	-4%
R2M2	-2%	-2%	-2%	-1%	-5%	-6%	-6%	-5%
R3M2	-19%	-39%	-61%	-61%	-17%	-40%	-62%	-64%
R4M2	-19%	-40%	-61%	-61%	-17%	-41%	-62%	-64%
R1VR1	-10%	-10%	-10%	-9%	-16%	-16%	-17%	-16%
R2VR2	-2%	-2%	-3%	-1%	-15%	-16%	-16%	-15%
R3VR3	-26%	-59%	-38%	-72%	-42%	-77%	-29%	-53%
R4VR4	-29%	-67%	-45%	-73%	-40%	-74%	-27%	-51%
R2VR3	5%	-5%	-12%	-2%	-14%	-28%	-22%	-25%
R3VR4	-29%	-64%	-37%	-71%	-42%	-77%	-28%	-52%
R1F1	-4%	-4%	-4%	-3%	-13%	-14%	-14%	-14%
R1F2	-4%	-3%	-4%	-3%	-16%	-16%	-16%	-16%
R4F1	-23%	90%	-57%	-79%	-20%	-13%	-15%	-45%
R4F2	-21%	112%	-58%	-79%	-17%	0%	-31%	-60%

Results of testing Ho: The relative difference between the true and estimated projected abundance is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4F2	Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject

Appendix E-31 Average and coefficient of variation (CV) of first year abundance across 1000 replicates by reader type(s)/scenarios (sample size = 100).

Age Sample Size = 100

Estimated value of first year abundance among reader(s)/scenarios.

True value of first year abundance is 95,390

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	93,353	94,122	93,567	93,537	94,059	94,414	93,969	93,883
R1	96,251	96,689	96,085	96,353	102,524	102,830	102,398	102,527
R2	96,427	96,798	96,262	96,753	102,414	102,974	102,368	102,438
R3	63,555	40,338	104,666	106,423	67,257	42,571	109,289	110,756
R4	63,561	40,305	104,835	106,624	67,133	42,650	109,215	110,684
R1M1	93,952	94,370	94,199	94,175	97,762	97,961	97,565	97,765
R2M1	93,381	94,224	93,464	93,778	95,577	96,029	95,206	95,504
R3M1	62,992	40,017	102,669	104,333	64,015	40,608	104,831	105,921
R4M1	62,235	39,459	102,233	104,173	62,068	39,352	102,562	104,009
R1M2	94,052	94,507	94,171	94,224	100,131	100,425	99,980	100,246
R2M2	94,318	95,130	94,372	94,684	100,253	100,775	99,933	100,457
R3M2	63,051	40,067	102,783	104,499	65,461	41,122	108,196	110,024
R4M2	63,102	39,983	103,018	104,832	65,428	41,149	108,208	110,222
R1VR1	97,473	97,922	97,585	97,804	111,610	111,935	110,967	111,563
R2VR2	94,875	95,036	94,642	94,770	101,305	101,637	101,145	101,224
R3VR3	68,729	45,446	121,222	160,540	88,691	66,267	120,003	135,285
R4VR4	70,032	48,200	102,482	148,105	85,497	64,184	117,621	132,604
R2VR3	92,446	96,233	98,541	96,597	92,035	94,727	112,595	109,115
R3VR4	69,923	47,144	119,605	159,668	89,026	66,924	119,456	134,666
R1F1	93,801	94,487	93,968	93,983	100,842	100,870	100,935	101,266
R1F2	93,918	94,646	94,157	94,092	105,844	105,999	105,817	106,582
R4F1	65,853	60,358	101,054	136,346	82,587	79,362	111,952	127,091
R4F2	64,736	57,822	102,297	114,090	82,798	76,820	123,720	143,997

Estimated value of the CV of first year abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	11%	10%	10%	11%	10%	10%	10%	10%
R1	8%	8%	8%	8%	7%	7%	7%	7%
R2	8%	7%	7%	7%	7%	7%	7%	7%
R3	8%	8%	7%	7%	7%	8%	7%	7%
R4	7%	8%	7%	7%	7%	8%	7%	7%
R1M1	10%	10%	9%	10%	8%	8%	8%	7%
R2M1	10%	9%	9%	9%	8%	8%	8%	7%
R3M1	8%	8%	10%	10%	8%	8%	7%	7%
R4M1	8%	8%	10%	10%	8%	9%	7%	7%
R1M2	10%	10%	10%	10%	7%	7%	7%	7%
R2M2	10%	9%	9%	9%	7%	7%	7%	7%
R3M2	8%	8%	10%	10%	7%	8%	7%	7%
R4M2	8%	8%	10%	10%	8%	8%	7%	7%
R1VR1	11%	11%	11%	11%	8%	8%	9%	8%
R2VR2	9%	9%	9%	9%	7%	7%	7%	7%
R3VR3	8%	8%	18%	11%	7%	8%	7%	7%
R4VR4	8%	8%	16%	9%	7%	8%	7%	7%
R2VR3	8%	7%	10%	7%	7%	7%	7%	7%
R3VR4	7%	8%	18%	11%	7%	8%	7%	7%
R1F1	11%	10%	10%	11%	12%	12%	12%	11%
R1F2	11%	10%	10%	11%	11%	12%	11%	11%
R4F1	7%	7%	7%	21%	8%	8%	7%	7%
R4F2	7%	7%	8%	22%	7%	7%	8%	7%

Appendix E-32 Relative error of first year abundance and results of the hypothesis test to determine if the estimated value of first year abundance is within 10% of the true value of first year abundance (sample size = 100).

Age Sample Size = 100
Relative error of first year abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-2%	-1%	-2%	-2%	-1%	-1%	-1%	-2%
R1	1%	1%	1%	1%	7%	8%	7%	7%
R2	1%	1%	1%	1%	7%	8%	7%	7%
R3	-33%	-58%	10%	12%	-29%	-55%	15%	16%
R4	-33%	-58%	10%	12%	-30%	-55%	14%	16%
R1M1	-2%	-1%	-1%	-1%	2%	3%	2%	2%
R2M1	-2%	-1%	-2%	-2%	0%	1%	0%	0%
R3M1	-34%	-58%	8%	9%	-33%	-57%	10%	11%
R4M1	-35%	-59%	7%	9%	-35%	-59%	8%	9%
R1M2	-1%	-1%	-1%	-1%	5%	5%	5%	5%
R2M2	-1%	0%	-1%	-1%	5%	6%	5%	5%
R3M2	-34%	-58%	8%	10%	-31%	-57%	13%	15%
R4M2	-34%	-58%	8%	10%	-31%	-57%	13%	16%
R1VR1	2%	3%	2%	3%	17%	17%	16%	17%
R2VR2	-1%	0%	-1%	-1%	6%	7%	6%	6%
R3VR3	-28%	-52%	27%	68%	-7%	-31%	26%	42%
R4VR4	-27%	-49%	7%	55%	-10%	-33%	23%	39%
R2VR3	-3%	1%	3%	1%	-4%	-1%	18%	14%
R3VR4	-27%	-51%	25%	67%	-7%	-30%	25%	41%
R1F1	-2%	-1%	-1%	-1%	6%	6%	6%	6%
R1F2	-2%	-1%	-1%	-1%	11%	11%	11%	12%
R4F1	-31%	-37%	6%	43%	-13%	-17%	17%	33%
R4F2	-32%	-39%	7%	20%	-13%	-19%	30%	51%

Results of testing Ho: The relative difference between the true and estimated first year abundance is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Reject
R4M1	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R4F2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject

Appendix E-33 Average and coefficient of variation (CV) of first year abundance across 1000 replicates by reader type(s)/scenarios (sample size = 300).

Age Sample Size = 300
Estimated value of first year abundance among reader(s)/scenarios.
True value of first year abundance is 95,390

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	94,878	94,861	94,409	94,284	94,687	94,211	94,544	94,298
R1	95,966	95,927	95,505	95,351	101,607	101,286	101,630	101,237
R2	96,047	96,077	95,590	95,486	101,635	101,151	101,593	101,268
R3	62,855	39,475	104,471	106,188	66,105	41,356	109,014	110,255
R4	62,813	39,331	104,398	106,146	66,178	41,482	108,696	109,871
R1M1	94,834	94,917	94,512	94,380	96,468	96,001	96,466	96,055
R2M1	94,017	94,034	93,608	93,548	94,230	93,921	94,184	93,895
R3M1	62,325	39,146	103,781	105,453	62,600	39,246	104,088	105,184
R4M1	61,494	38,518	103,040	104,932	60,504	37,989	101,958	103,130
R1M2	94,990	94,971	94,601	94,420	99,160	98,773	99,128	98,740
R2M2	95,091	95,018	94,631	94,486	99,439	99,023	99,294	98,985
R3M2	62,345	39,145	103,841	105,599	64,300	40,034	107,773	109,200
R4M2	62,320	39,142	103,850	105,605	64,386	39,944	107,883	109,448
R1VR1	99,308	99,290	98,891	98,787	111,421	110,816	111,347	110,986
R2VR2	95,048	95,088	94,642	94,562	100,331	100,059	100,413	99,975
R3VR3	68,025	44,398	140,348	172,793	87,669	65,012	119,741	134,410
R4VR4	69,366	47,176	129,853	165,048	84,304	62,703	117,303	131,780
R2VR3	91,950	95,315	99,535	95,628	91,147	93,069	112,018	107,824
R3VR4	69,235	46,098	139,206	171,173	88,091	65,641	119,079	133,685
R1F1	95,284	95,263	94,946	94,772	102,342	101,911	102,258	101,978
R1F2	95,548	95,438	95,048	94,950	108,234	107,687	108,056	107,670
R4F1	65,157	59,297	100,625	156,002	81,268	77,404	111,027	126,170
R4F2	63,995	56,704	102,197	152,540	81,610	75,188	123,707	143,281

Estimated value of the CV of first year abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	6%	6%	6%	6%	6%	6%	6%	6%
R1	6%	6%	6%	6%	6%	6%	6%	6%
R2	6%	6%	6%	6%	6%	6%	6%	6%
R3	6%	6%	6%	6%	6%	6%	6%	6%
R4	6%	6%	6%	6%	6%	6%	6%	6%
R1M1	6%	6%	6%	6%	6%	6%	6%	6%
R2M1	6%	6%	6%	6%	7%	6%	6%	6%
R3M1	6%	6%	6%	6%	6%	6%	6%	6%
R4M1	6%	6%	6%	6%	6%	6%	6%	6%
R1M2	6%	6%	6%	6%	6%	6%	6%	6%
R2M2	6%	6%	6%	6%	6%	6%	6%	6%
R3M2	6%	6%	6%	6%	6%	6%	6%	6%
R4M2	6%	6%	6%	6%	6%	6%	6%	6%
R1VR1	6%	6%	7%	6%	6%	6%	6%	6%
R2VR2	6%	6%	6%	6%	6%	6%	6%	6%
R3VR3	6%	6%	7%	6%	6%	6%	6%	6%
R4VR4	6%	6%	14%	8%	6%	6%	6%	6%
R2VR3	6%	6%	6%	6%	6%	6%	6%	6%
R3VR4	6%	6%	7%	6%	6%	6%	6%	6%
R1F1	6%	6%	6%	6%	7%	6%	7%	6%
R1F2	6%	6%	6%	6%	6%	6%	6%	6%
R4F1	6%	6%	6%	7%	6%	6%	6%	6%
R4F2	6%	6%	6%	14%	6%	6%	6%	6%

Appendix E-34 Relative error of first year abundance and results of the hypothesis test to determine if the estimated value of first year abundance is within 10% of the true value of first year abundance (sample size = 300).

Age Sample Size = 300
Relative error of first year abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%
R1	1%	1%	0%	0%	7%	6%	7%	6%
R2	1%	1%	0%	0%	7%	3%	7%	6%
R3	-34%	-59%	10%	11%	-31%	-57%	14%	16%
R4	-34%	-59%	9%	11%	-31%	-57%	14%	15%
R1M1	-1%	0%	-1%	-1%	1%	1%	1%	1%
R2M1	-1%	-1%	-2%	-2%	-1%	-2%	-1%	-2%
R3M1	-35%	-59%	9%	11%	-34%	-59%	9%	10%
R4M1	-36%	-60%	8%	10%	-37%	-60%	7%	8%
R1M2	0%	0%	-1%	-1%	4%	4%	4%	4%
R2M2	0%	0%	-1%	-1%	4%	4%	4%	4%
R3M2	-35%	-59%	9%	11%	-33%	-58%	13%	14%
R4M2	-35%	-59%	9%	11%	-33%	-58%	13%	15%
R1VR1	4%	4%	4%	4%	17%	16%	17%	16%
R2VR2	0%	0%	-1%	-1%	5%	5%	5%	5%
R3VR3	-29%	-53%	47%	81%	-8%	-32%	26%	41%
R4VR4	-27%	-51%	36%	73%	-12%	-34%	23%	38%
R2VR3	-4%	0%	4%	0%	-4%	-2%	17%	13%
R3VR4	-27%	-52%	46%	79%	-8%	-31%	25%	40%
R1F1	0%	0%	0%	-1%	7%	7%	7%	7%
R1F2	0%	0%	0%	0%	13%	13%	13%	13%
R4F1	-32%	-38%	5%	64%	-15%	-19%	16%	32%
R4F2	-33%	-41%	7%	60%	-14%	-21%	30%	-33%

Results of testing Ho: The relative difference between the true and estimated first year abundance is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject
R4M1	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R4F2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject

Appendix E-35 Average and coefficient of variation (CV) of first year abundance across 1000 replicates by reader type(s)/scenarios (sample size = 900).

Age Sample Size = 900
Estimated value of first year abundance among reader(s)/scenarios.
True value of first year abundance is 95,390

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	94,416	94,369	94,135	94,540	94,539	94,106	94,064	94,256
R1	95,506	95,498	95,172	95,660	101,499	101,118	101,019	101,327
R2	95,573	95,675	95,273	95,728	101,482	101,129	101,057	101,272
R3	62,392	39,095	104,166	106,724	65,976	41,051	108,446	110,433
R4	62,361	39,021	104,179	106,572	65,904	41,101	108,418	110,195
R1M1	94,483	94,456	94,151	94,607	96,254	95,837	95,832	96,030
R2M1	93,595	93,584	93,305	93,735	93,962	93,621	93,558	93,783
R3M1	61,782	38,862	103,529	105,916	62,238	38,926	103,497	105,428
R4M1	61,040	38,257	102,816	105,339	60,165	37,571	101,615	103,335
R1M2	94,570	94,566	94,183	94,671	99,128	98,669	98,561	98,820
R2M2	94,546	94,588	94,240	94,736	99,261	98,865	98,870	99,059
R3M2	61,924	38,841	103,609	106,170	64,097	39,747	107,301	109,463
R4M2	61,952	38,801	103,740	106,148	64,126	39,680	107,502	109,656
R1VR1	98,746	98,854	98,503	99,022	111,297	110,794	110,669	110,926
R2VR2	94,713	94,641	94,296	94,758	100,272	99,837	99,815	100,064
R3VR3	67,658	44,033	140,548	173,855	87,588	64,640	119,109	134,653
R4VR4	68,866	46,802	136,947	169,554	84,274	62,390	116,810	131,757
R2VR3	91,496	94,931	99,253	95,895	90,940	92,962	111,438	107,952
R3VR4	68,784	45,655	139,303	172,034	87,944	65,399	118,530	133,767
R1F1	94,817	94,823	94,582	95,061	102,052	101,656	101,576	101,784
R1F2	95,080	95,036	94,662	95,134	108,078	107,600	107,560	107,813
R4F1	64,724	58,865	107,807	161,662	81,006	77,165	110,528	126,325
R4F2	63,508	56,262	107,929	164,571	81,467	75,068	123,108	143,803

Estimated value of the CV of first year abundance among reader(s)/scenarios.

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	6%	6%	6%	6%	6%	6%	6%	6%
R1	6%	6%	6%	6%	6%	6%	6%	6%
R2	6%	6%	6%	6%	6%	6%	6%	6%
R3	5%	5%	6%	6%	6%	6%	6%	6%
R4	5%	5%	6%	6%	6%	5%	6%	6%
R1M1	6%	6%	6%	6%	6%	5%	6%	6%
R2M1	6%	6%	6%	6%	6%	6%	6%	6%
R3M1	5%	5%	6%	6%	6%	6%	6%	6%
R4M1	5%	5%	6%	6%	6%	5%	6%	6%
R1M2	6%	6%	6%	6%	6%	5%	6%	6%
R2M2	6%	6%	6%	6%	6%	6%	6%	6%
R3M2	5%	5%	6%	6%	6%	6%	6%	6%
R4M2	5%	5%	6%	6%	6%	5%	6%	6%
R1VR1	6%	6%	6%	6%	6%	5%	6%	6%
R2VR2	6%	6%	6%	6%	6%	6%	6%	6%
R3VR3	5%	5%	6%	6%	6%	6%	6%	6%
R4VR4	5%	5%	6%	6%	6%	6%	6%	6%
R2VR3	6%	6%	6%	6%	6%	6%	6%	6%
R3VR4	6%	5%	6%	6%	6%	6%	6%	6%
R1F1	6%	6%	6%	6%	6%	6%	6%	6%
R1F2	6%	6%	6%	6%	6%	6%	6%	6%
R4F1	5%	5%	16%	8%	6%	6%	6%	6%
R4F2	5%	5%	15%	8%	6%	6%	6%	6%

Appendix E-36 Relative error of first year abundance and results of the hypothesis test to determine if the estimated value of first year abundance is within 10% of the true value of first year abundance (sample size = 900).

Age Sample Size = 900
Relative error of first year abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%
R1	0%	0%	0%	0%	6%	6%	6%	6%
R2	0%	0%	0%	0%	6%	6%	6%	6%
R3	-35%	-59%	9%	12%	-31%	-57%	14%	16%
R4	-35%	-59%	9%	12%	-31%	-57%	14%	16%
R1M1	-1%	-1%	-1%	-1%	1%	0%	0%	1%
R2M1	-2%	-2%	-2%	-2%	-1%	-2%	-2%	-2%
R3M1	-35%	-59%	9%	11%	-35%	-59%	8%	11%
R4M1	-36%	-60%	8%	10%	-37%	-61%	7%	8%
R1M2	-1%	-1%	-1%	-1%	4%	3%	3%	4%
R2M2	-1%	-1%	-1%	-1%	4%	4%	4%	4%
R3M2	-35%	-59%	9%	11%	-33%	-58%	12%	15%
R4M2	-35%	-59%	9%	11%	-33%	-58%	13%	15%
R1VR1	4%	4%	3%	4%	17%	16%	16%	16%
R2VR2	-1%	-1%	-1%	-1%	5%	5%	5%	5%
R3VR3	-29%	-54%	47%	82%	-8%	-32%	25%	41%
R4VR4	-28%	-51%	44%	78%	-12%	-35%	22%	38%
R2VR3	-4%	0%	4%	1%	-5%	-3%	17%	13%
R3VR4	-28%	-52%	46%	80%	-8%	-31%	24%	40%
R1F1	-1%	-1%	-1%	0%	7%	7%	6%	7%
R1F2	0%	0%	-1%	0%	13%	13%	13%	13%
R4F1	-32%	-38%	13%	69%	-15%	-19%	16%	32%
R4F2	-33%	-41%	13%	73%	-15%	-21%	29%	51%

Results of testing Ho: The relative difference between the true and estimated first year abundance is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4M1	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4F2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject

Appendix E-37 Average and coefficient of variation (CV) of last year abundance across 1000 replicates by reader type(s)/scenarios (sample size = 100).

Age Sample Size = 100
Estimated value of last year abundance among reader(s)/scenarios.
True value of last year abundance is 130,222

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	126,225	126,860	126,709	126,000	127,160	125,959	126,214	126,681
R1	127,335	128,194	128,134	127,324	117,015	116,286	115,895	116,501
R2	127,959	129,188	128,311	127,787	115,773	114,672	115,739	115,548
R3	103,445	67,632	61,422	61,864	104,564	70,017	60,956	61,893
R4	103,419	66,844	61,250	61,786	103,228	68,500	61,212	61,953
R1M1	126,485	126,991	126,615	126,129	122,811	122,675	121,881	123,105
R2M1	128,179	128,952	128,626	128,111	126,226	124,733	125,584	125,916
R3M1	102,845	67,186	63,490	63,956	101,532	65,553	62,654	63,675
R4M1	104,154	67,222	63,447	63,699	102,717	64,846	63,810	64,795
R1M2	126,571	127,130	126,864	126,308	129,289	129,144	128,360	129,262
R2M2	126,720	127,480	127,185	126,670	129,380	127,704	128,327	128,556
R3M2	103,021	67,330	63,470	63,937	106,718	68,679	60,207	61,109
R4M2	103,155	67,026	63,020	63,415	106,352	68,238	60,170	61,023
R1VR1	118,855	119,515	119,155	118,791	117,555	116,767	116,179	116,821
R2VR2	126,140	127,340	127,159	126,450	118,977	117,821	117,983	118,529
R3VR3	97,200	54,232	79,865	49,420	85,348	39,546	105,635	79,111
R4VR4	95,429	47,269	71,652	48,047	87,387	42,328	107,552	81,421
R2VR3	136,085	127,384	117,905	126,681	118,144	102,059	112,754	108,212
R3VR4	94,901	49,820	81,813	50,498	84,936	39,242	105,970	80,232
R1F1	124,866	125,379	125,177	124,642	115,499	114,522	115,211	115,857
R1F2	125,143	125,646	125,502	124,962	114,960	114,051	114,342	115,077
R4F1	99,982	189,980	63,431	50,369	110,000	113,908	118,736	87,262
R4F2	101,980	202,931	62,685	59,098	113,701	125,719	100,421	69,686

Estimated value of the CV of last year abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	15%	14%	15%	15%	14%	15%	14%	14%
R1	16%	15%	15%	16%	15%	15%	15%	15%
R2	15%	15%	15%	16%	14%	15%	14%	15%
R3	17%	17%	12%	12%	15%	16%	12%	12%
R4	16%	17%	12%	12%	15%	16%	12%	12%
R1M1	15%	14%	15%	16%	15%	16%	15%	16%
R2M1	15%	14%	15%	16%	15%	16%	15%	16%
R3M1	17%	17%	12%	12%	16%	17%	12%	12%
R4M1	17%	17%	12%	12%	16%	17%	12%	12%
R1M2	15%	14%	15%	15%	15%	15%	15%	15%
R2M2	15%	14%	15%	16%	15%	15%	15%	15%
R3M2	17%	17%	12%	12%	15%	17%	11%	12%
R4M2	17%	17%	12%	12%	15%	17%	11%	12%
R1VR1	15%	14%	14%	15%	15%	16%	16%	16%
R2VR2	15%	14%	15%	16%	14%	15%	15%	15%
R3VR3	16%	16%	23%	16%	14%	14%	15%	14%
R4VR4	16%	16%	22%	14%	14%	14%	15%	14%
R2VR3	16%	15%	15%	16%	15%	14%	15%	15%
R3VR4	16%	16%	22%	16%	14%	14%	15%	14%
R1F1	15%	14%	15%	15%	16%	16%	16%	15%
R1F2	15%	14%	15%	15%	15%	15%	15%	15%
R4F1	16%	16%	12%	11%	15%	15%	16%	15%
R4F2	16%	16%	12%	14%	15%	15%	15%	13%

Appendix E-38 Relative error of last year abundance and results of the hypothesis test to determine if the estimated value of last year abundance is within 10% of the true value of last year abundance (sample size = 100).

Age Sample Size = 100
Relative error of last year abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-3%	-3%	-3%	-3%	-2%	-3%	-3%	-3%
R1	-2%	-2%	-2%	-2%	-10%	-11%	-11%	-11%
R2	-2%	-1%	-1%	-2%	-11%	-12%	-11%	-11%
R3	-21%	-48%	-53%	-52%	-20%	-46%	-53%	-52%
R4	-21%	-49%	-53%	-53%	-21%	-47%	-53%	-52%
R1M1	-3%	-2%	-3%	-3%	-6%	-6%	-6%	-5%
R2M1	-2%	-1%	-1%	-2%	-3%	-4%	-4%	-3%
R3M1	-21%	-48%	-51%	-51%	-22%	-50%	-52%	-51%
R4M1	-20%	-48%	-51%	-51%	-21%	-50%	-51%	-50%
R1M2	-3%	-2%	-3%	-3%	-1%	-1%	-1%	-1%
R2M2	-3%	-2%	-2%	-3%	-1%	-2%	-1%	-1%
R3M2	-21%	-48%	-51%	-51%	-18%	-47%	-54%	-53%
R4M2	-21%	-49%	-52%	-51%	-18%	-48%	-54%	-53%
R1VR1	-9%	-8%	-8%	-9%	-10%	-10%	-11%	-10%
R2VR2	-3%	-2%	-2%	-3%	-9%	-10%	-9%	-9%
R3VR3	-25%	-58%	-39%	-62%	-34%	-70%	-19%	-39%
R4VR4	-27%	-64%	-45%	-63%	-33%	-67%	-17%	-37%
R2VR3	5%	-2%	-9%	-3%	-9%	-22%	-13%	-17%
R3VR4	-27%	-62%	-37%	-61%	-35%	-70%	-19%	-38%
R1F1	-4%	-4%	-4%	-4%	-11%	-12%	-12%	-11%
R1F2	-4%	-4%	-4%	-4%	-12%	-12%	-12%	-12%
R4F1	-23%	46%	-51%	-61%	-16%	-13%	-9%	-33%
R4F2	-22%	56%	-52%	-55%	-13%	-3%	-23%	-46%

Results of testing Ho: The relative difference between the true and estimated last year abundance is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4F2	Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject

Appendix E-39 Average and coefficient of variation (CV) of last year abundance across 1000 replicates by reader type(s)/scenarios (sample size = 300).

Age Sample Size = 300
Estimated value of last year abundance among reader(s)/scenarios.
True value of last year abundance is 130,222

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	127,166	127,401	126,063	126,611	127,295	125,754	126,342	125,812
R1	129,287	129,714	128,239	128,947	117,760	116,615	116,732	116,288
R2	129,829	129,958	128,670	129,269	116,231	115,403	115,633	115,001
R3	104,946	69,517	61,105	61,362	105,292	70,407	61,219	61,275
R4	104,827	68,599	61,275	61,503	103,429	68,961	61,407	61,493
R1M1	127,519	127,758	126,373	127,006	124,268	123,133	123,389	122,774
R2M1	129,469	129,881	128,337	128,869	127,560	126,314	126,689	126,527
R3M1	104,311	69,125	60,989	61,300	102,444	66,213	62,982	63,023
R4M1	105,608	69,051	61,394	61,666	104,621	65,533	64,192	64,352
R1M2	127,605	127,907	126,537	127,171	130,424	129,337	129,682	128,937
R2M2	127,904	128,329	126,819	127,396	129,996	128,759	129,048	128,914
R3M2	104,463	69,198	60,948	61,254	107,630	69,149	60,502	60,529
R4M2	104,571	68,876	60,983	61,313	107,453	68,359	60,457	60,529
R1VR1	119,791	120,102	118,664	119,357	117,779	117,162	117,320	116,577
R2VR2	127,983	128,356	126,994	127,519	119,667	118,373	118,849	118,126
R3VR3	98,527	55,020	94,748	54,026	85,750	38,818	106,064	78,384
R4VR4	96,205	47,532	82,118	51,241	87,800	41,653	108,365	80,469
R2VR3	138,091	128,490	117,669	128,250	119,059	102,096	113,564	107,856
R3VR4	95,989	50,346	95,972	55,131	84,991	38,503	107,207	79,421
R1F1	125,790	126,010	124,622	125,258	116,581	115,438	115,721	115,019
R1F2	126,052	126,314	124,944	125,556	115,441	114,516	114,761	114,091
R4F1	101,226	193,632	63,451	42,714	111,018	114,176	119,939	86,400
R4F2	103,355	207,433	62,206	44,261	114,580	126,178	101,368	69,329

Estimated value of the CV of last year abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	13%	14%	14%	14%	14%	14%	14%	14%
R1	13%	14%	14%	14%	14%	14%	14%	14%
R2	13%	14%	14%	14%	14%	14%	14%	14%
R3	14%	17%	12%	12%	15%	17%	12%	12%
R4	14%	17%	12%	12%	15%	16%	12%	12%
R1M1	13%	14%	14%	14%	15%	15%	14%	14%
R2M1	13%	14%	14%	14%	15%	15%	14%	14%
R3M1	14%	17%	12%	12%	15%	17%	12%	12%
R4M1	15%	18%	12%	12%	16%	17%	12%	12%
R1M2	13%	14%	14%	14%	15%	15%	14%	14%
R2M2	13%	14%	14%	14%	15%	14%	14%	14%
R3M2	14%	17%	12%	12%	15%	17%	12%	12%
R4M2	14%	17%	12%	12%	15%	17%	12%	12%
R1VR1	13%	14%	14%	14%	14%	14%	14%	14%
R2VR2	13%	14%	14%	14%	14%	14%	14%	14%
R3VR3	14%	16%	15%	13%	14%	15%	14%	13%
R4VR4	14%	16%	15%	12%	14%	15%	14%	13%
R2VR3	14%	14%	14%	14%	14%	14%	14%	13%
R3VR4	14%	16%	15%	12%	14%	14%	14%	13%
R1F1	13%	14%	14%	14%	15%	14%	14%	14%
R1F2	13%	14%	14%	14%	14%	14%	14%	14%
R4F1	14%	16%	16%	11%	15%	15%	15%	13%
R4F2	14%	16%	15%	10%	15%	15%	14%	12%

Appendix E-40 Relative error of last year abundance and results of the hypothesis test to determine if the estimated value of last year abundance is within 10% of the true value of last year abundance (sample size = 300).

Age Sample Size = 300
Relative error of last year abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-2%	-2%	-3%	-3%	-2%	-3%	-3%	-3%
R1	-1%	0%	-2%	-1%	-10%	-10%	-10%	-11%
R2	0%	0%	-1%	-1%	-11%	-11%	-11%	-12%
R3	-19%	-47%	-53%	-53%	-19%	-46%	-53%	-53%
R4	-20%	-47%	-53%	-53%	-21%	-47%	-53%	-53%
R1M1	-2%	-2%	-3%	-2%	-5%	-5%	-5%	-6%
R2M1	-1%	0%	-1%	-1%	-2%	-3%	-3%	-3%
R3M1	-20%	-47%	-53%	-53%	-21%	-49%	-52%	-52%
R4M1	-19%	-47%	-53%	-53%	-20%	-50%	-51%	-51%
R1M2	-2%	-2%	-3%	-2%	0%	-1%	0%	-1%
R2M2	-2%	-1%	-3%	-2%	0%	-1%	-1%	-1%
R3M2	-20%	-47%	-53%	-53%	-17%	-47%	-54%	-54%
R4M2	-20%	-47%	-53%	-53%	-17%	-48%	-54%	-54%
R1VR1	-8%	-8%	-9%	-8%	-10%	-10%	-10%	-10%
R2VR2	-2%	-1%	-2%	-2%	-8%	-9%	-9%	-9%
R3VR3	-24%	-58%	-27%	-59%	-34%	-70%	-19%	-40%
R4VR4	-26%	-63%	-37%	-61%	-33%	-68%	-17%	-38%
R2VR3	6%	-1%	-10%	-2%	-9%	-22%	-13%	-17%
R3VR4	-26%	-61%	-26%	-58%	-35%	-70%	-18%	-39%
R1F1	-3%	-3%	-4%	-4%	-10%	-11%	-11%	-12%
R1F2	-3%	-3%	-4%	-4%	-11%	-12%	-12%	-12%
R4F1	-22%	49%	-51%	-67%	-15%	-12%	-8%	-34%
R4F2	-21%	59%	-52%	-66%	-12%	-3%	-22%	-21%

Results of testing Ho: The relative difference between the true and estimated last year abundance is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4F2	Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject

Appendix E-41 Average and coefficient of variation (CV) of last year abundance across 1000 replicates by reader type(s)/scenarios (sample size = 900).

Age Sample Size = 900
Estimated value of last year abundance among reader(s)/scenarios.
True value of last year abundance is 130,222

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	127,314	127,673	127,073	128,484	127,845	127,037	126,760	127,823
R1	129,509	129,950	129,357	130,737	117,909	117,287	116,989	117,758
R2	129,653	130,027	129,632	131,170	116,722	116,103	115,775	116,561
R3	105,644	69,725	61,191	62,087	105,619	71,681	61,235	61,841
R4	105,441	68,823	61,345	62,188	104,293	70,312	61,394	61,936
R1M1	127,712	128,035	127,405	128,855	124,763	124,186	123,574	124,789
R2M1	129,701	130,015	129,409	130,889	128,133	127,517	127,273	128,336
R3M1	104,895	69,373	61,081	62,008	103,215	67,801	63,029	63,602
R4M1	106,198	69,476	61,414	62,433	105,160	67,079	64,223	64,921
R1M2	127,866	128,163	127,575	129,030	130,912	130,399	129,791	131,077
R2M2	128,187	128,443	127,906	129,336	130,394	129,833	129,609	130,582
R3M2	105,040	69,453	61,033	61,971	108,225	70,596	60,483	61,064
R4M2	105,058	69,158	61,035	62,017	107,994	69,845	60,439	61,016
R1VR1	119,897	120,154	119,650	120,867	118,278	117,765	117,401	118,372
R2VR2	128,171	128,585	127,975	129,414	119,746	119,152	119,003	119,568
R3VR3	98,925	54,922	95,716	55,019	85,752	39,119	106,527	78,870
R4VR4	96,602	47,488	83,891	52,267	87,876	42,012	108,505	81,468
R2VR3	138,230	128,707	118,722	130,048	119,346	102,794	113,547	109,310
R3VR4	96,327	50,164	96,672	55,916	85,199	38,702	107,351	80,003
R1F1	125,926	126,246	125,630	127,013	117,270	116,371	116,307	116,907
R1F2	126,144	126,520	125,948	127,362	116,004	115,234	115,219	115,966
R4F1	101,666	194,502	65,960	43,485	111,389	115,517	120,240	87,550
R4F2	103,743	208,599	64,109	42,507	115,046	127,638	101,833	70,007

Estimated value of the CV of last year abundance among reader(s)/scenarios.

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	13%	14%	14%	14%	14%	14%	14%	14%
R1	13%	14%	14%	14%	14%	14%	14%	13%
R2	13%	14%	14%	14%	14%	14%	14%	13%
R3	14%	17%	12%	12%	15%	16%	12%	12%
R4	14%	17%	12%	11%	15%	16%	12%	12%
R1M1	13%	14%	14%	14%	15%	15%	14%	14%
R2M1	13%	14%	14%	14%	15%	15%	14%	14%
R3M1	14%	17%	12%	12%	15%	17%	12%	12%
R4M1	14%	17%	12%	12%	16%	17%	12%	12%
R1M2	13%	14%	14%	14%	15%	15%	14%	14%
R2M2	13%	14%	14%	14%	15%	14%	14%	14%
R3M2	14%	17%	12%	12%	15%	17%	12%	12%
R4M2	14%	17%	12%	12%	15%	17%	12%	12%
R1VR1	13%	14%	14%	13%	14%	14%	14%	14%
R2VR2	13%	14%	14%	14%	14%	14%	14%	13%
R3VR3	14%	16%	15%	12%	14%	14%	14%	13%
R4VR4	14%	16%	14%	12%	14%	14%	14%	12%
R2VR3	14%	14%	14%	14%	14%	14%	14%	13%
R3VR4	14%	16%	15%	12%	14%	14%	14%	13%
R1F1	13%	14%	14%	14%	15%	14%	14%	14%
R1F2	13%	14%	14%	14%	14%	14%	14%	14%
R4F1	14%	16%	15%	11%	15%	15%	14%	13%
R4F2	14%	16%	15%	11%	15%	15%	14%	12%

Appendix E-42 Relative error of last year abundance and results of the hypothesis test to determine if the estimated value of last year abundance is within 10% of the true value of last year abundance (sample size = 900).

Age Sample Size = 900
Relative error of last year abundance among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	-2%	-2%	-2%	-1%	-2%	-2%	-3%	-2%
R1	-1%	0%	-1%	0%	-9%	-10%	-10%	-10%
R2	0%	0%	0%	1%	-10%	-11%	-11%	-10%
R3	-19%	-46%	-53%	-52%	-19%	-45%	-53%	-53%
R4	-19%	-47%	-53%	-52%	-20%	-46%	-53%	-52%
R1M1	-2%	-2%	-2%	-1%	-4%	-5%	-5%	-4%
R2M1	0%	0%	-1%	1%	-2%	-2%	-2%	-1%
R3M1	-19%	-47%	-53%	-52%	-21%	-48%	-52%	-51%
R4M1	-18%	-47%	-53%	-52%	-19%	-48%	-51%	-50%
R1M2	-2%	-2%	-2%	-1%	1%	0%	0%	1%
R2M2	-2%	-1%	-2%	-1%	0%	0%	0%	0%
R3M2	-19%	-47%	-53%	-52%	-17%	-46%	-54%	-53%
R4M2	-19%	-47%	-53%	-52%	-17%	-46%	-54%	-53%
R1VR1	-8%	-8%	-8%	-7%	-9%	-10%	-10%	-9%
R2VR2	-2%	-1%	-2%	-1%	-8%	-9%	-9%	-8%
R3VR3	-24%	-58%	-26%	-58%	-34%	-70%	-18%	-39%
R4VR4	-26%	-64%	-36%	-60%	-33%	-68%	-17%	-37%
R2VR3	6%	-1%	-9%	0%	-8%	-21%	-13%	-16%
R3VR4	-26%	-61%	-26%	-57%	-35%	-70%	-18%	-39%
R1F1	-3%	-3%	-4%	-2%	-10%	-11%	-11%	-10%
R1F2	-3%	-3%	-3%	-2%	-11%	-12%	-12%	-11%
R4F1	-22%	49%	-49%	-67%	-14%	-11%	-8%	-33%
R4F2	-20%	60%	-51%	-67%	-12%	-2%	-22%	-46%

Results of testing Ho: The relative difference between the true and estimated last year abundance is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject
R3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject
R4F2	Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject

Appendix E-43 Average and coefficient of variation (CV) of first year fishing mortality across 1000 replicates by reader type(s)/scenarios (sample size = 100).

Age Sample Size = 100
Estimated value of first year fishing mortality among reader(s)/scenarios.
True value of first year fishing mortality is 0.330

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.331	0.330	0.332	0.330	0.330	0.329	0.332	0.329
R1	0.323	0.322	0.323	0.320	0.278	0.277	0.279	0.277
R2	0.321	0.319	0.321	0.319	0.276	0.275	0.278	0.275
R3	0.328	0.318	0.219	0.215	0.328	0.336	0.201	0.198
R4	0.328	0.318	0.218	0.214	0.327	0.336	0.201	0.197
R1M1	0.331	0.327	0.331	0.329	0.301	0.300	0.299	0.301
R2M1	0.335	0.334	0.335	0.334	0.308	0.308	0.311	0.309
R3M1	0.327	0.314	0.226	0.222	0.330	0.327	0.212	0.209
R4M1	0.332	0.319	0.227	0.222	0.340	0.338	0.217	0.213
R1M2	0.331	0.329	0.331	0.329	0.303	0.302	0.304	0.303
R2M2	0.331	0.329	0.331	0.329	0.302	0.300	0.303	0.301
R3M2	0.327	0.315	0.225	0.222	0.333	0.329	0.208	0.204
R4M2	0.328	0.315	0.225	0.221	0.333	0.332	0.208	0.203
R1VR1	0.314	0.312	0.313	0.312	0.277	0.278	0.279	0.277
R2VR2	0.330	0.327	0.329	0.327	0.283	0.281	0.285	0.283
R3VR3	0.303	0.258	0.224	0.156	0.250	0.191	0.241	0.193
R4VR4	0.296	0.234	0.232	0.157	0.256	0.200	0.249	0.199
R2VR3	0.335	0.312	0.310	0.320	0.294	0.267	0.265	0.261
R3VR4	0.296	0.241	0.227	0.157	0.249	0.190	0.242	0.195
R1F1	0.328	0.327	0.329	0.327	0.298	0.299	0.301	0.301
R1F2	0.329	0.327	0.329	0.327	0.289	0.288	0.290	0.290
R4F1	0.314	0.661	0.227	0.179	0.298	0.328	0.274	0.214
R4F2	0.321	0.732	0.225	0.207	0.300	0.360	0.244	0.181

Estimated value of the CV of first year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	10%	10%	10%	10%	10%	10%	10%	10%
R1	10%	10%	10%	10%	10%	10%	10%	9%
R2	10%	10%	10%	10%	10%	10%	10%	9%
R3	12%	14%	9%	9%	11%	14%	9%	9%
R4	12%	14%	9%	9%	12%	14%	9%	9%
R1M1	10%	10%	10%	10%	10%	10%	10%	10%
R2M1	10%	10%	10%	10%	10%	11%	11%	10%
R3M1	12%	14%	12%	12%	13%	15%	9%	9%
R4M1	12%	15%	12%	12%	13%	16%	9%	9%
R1M2	10%	10%	10%	10%	10%	10%	10%	10%
R2M2	10%	10%	10%	10%	10%	10%	10%	9%
R3M2	12%	15%	12%	12%	12%	14%	9%	8%
R4M2	12%	15%	11%	12%	12%	14%	9%	8%
R1VR1	10%	10%	10%	10%	9%	9%	10%	10%
R2VR2	10%	10%	10%	10%	10%	10%	10%	9%
R3VR3	11%	13%	9%	10%	10%	11%	9%	9%
R4VR4	12%	13%	9%	8%	10%	12%	9%	9%
R2VR3	10%	10%	10%	10%	10%	10%	9%	9%
R3VR4	11%	13%	9%	9%	10%	11%	9%	9%
R1F1	10%	10%	10%	10%	11%	11%	11%	10%
R1F2	10%	10%	10%	10%	9%	10%	10%	9%
R4F1	12%	12%	9%	20%	11%	12%	10%	9%
R4F2	12%	12%	9%	17%	11%	11%	9%	8%

Appendix E-44 Relative error of first year fishing mortality and results of the hypothesis test to determine if the estimated value of first year fishing mortality is within 10% of the true value of first year fishing mortality (sample size = 100).

Age Sample Size = 100
Relative error of first year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0%	0%	0%	0%	0%	0%	1%	0%
R1	-2%	-3%	-2%	-3%	-16%	-16%	-15%	-16%
R2	-3%	-3%	-3%	-3%	-16%	-17%	-16%	-17%
R3	0%	-4%	-34%	-35%	-1%	2%	-39%	-40%
R4	-1%	-4%	-34%	-35%	-1%	2%	-39%	-40%
R1M1	0%	-1%	0%	0%	-9%	-9%	-9%	-9%
R2M1	2%	1%	2%	1%	-7%	-7%	-6%	-6%
R3M1	-1%	-5%	-32%	-33%	0%	-1%	-36%	-37%
R4M1	1%	-3%	-31%	-33%	3%	2%	-34%	-35%
R1M2	0%	0%	0%	0%	-8%	-8%	-8%	-8%
R2M2	0%	0%	0%	0%	-9%	-9%	-8%	-9%
R3M2	-1%	-5%	-32%	-33%	1%	0%	-37%	-38%
R4M2	-1%	-4%	-32%	-33%	1%	0%	-37%	-38%
R1VR1	-5%	-5%	-5%	-6%	-16%	-16%	-16%	-16%
R2VR2	0%	-1%	0%	-1%	-14%	-15%	-14%	-14%
R3VR3	-8%	-22%	-32%	-53%	-24%	-42%	-27%	-42%
R4VR4	-10%	-29%	-30%	-52%	-22%	-39%	-25%	-40%
R2VR3	1%	-5%	-6%	-3%	-11%	-19%	-20%	-21%
R3VR4	-10%	-27%	-31%	-53%	-25%	-42%	-27%	-41%
R1F1	-1%	-1%	0%	-1%	-10%	-9%	-9%	-9%
R1F2	0%	-1%	0%	-1%	-12%	-13%	-12%	-12%
R4F1	-5%	100%	-31%	-46%	-10%	-1%	-17%	-35%
R4F2	-3%	122%	-32%	-37%	-9%	9%	-26%	-45%

Results of testing Ho: The relative difference between the true and estimated first year fishing mortality is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject

Appendix E-45 Average and coefficient of variation (CV) of first year fishing mortality across 1000 replicates by reader type(s)/scenarios (sample size = 300).

Age Sample Size = 300
Estimated value of first year fishing mortality among reader(s)/scenarios.
True value of first year fishing mortality is 0.330

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.334	0.333	0.335	0.334	0.334	0.336	0.333	0.335
R1	0.324	0.323	0.324	0.325	0.280	0.280	0.279	0.280
R2	0.322	0.321	0.322	0.324	0.278	0.280	0.278	0.279
R3	0.330	0.327	0.218	0.214	0.331	0.346	0.200	0.197
R4	0.330	0.327	0.217	0.214	0.329	0.343	0.200	0.197
R1M1	0.331	0.332	0.334	0.335	0.303	0.304	0.303	0.303
R2M1	0.335	0.336	0.338	0.339	0.312	0.314	0.312	0.314
R3M1	0.329	0.324	0.223	0.218	0.335	0.335	0.213	0.209
R4M1	0.334	0.327	0.224	0.220	0.348	0.347	0.217	0.213
R1M2	0.332	0.330	0.334	0.334	0.305	0.307	0.305	0.306
R2M2	0.333	0.331	0.334	0.334	0.305	0.306	0.303	0.304
R3M2	0.329	0.323	0.223	0.218	0.337	0.338	0.209	0.205
R4M2	0.329	0.324	0.223	0.218	0.338	0.339	0.208	0.205
R1VR1	0.315	0.314	0.316	0.317	0.280	0.280	0.280	0.281
R2VR2	0.330	0.330	0.332	0.332	0.285	0.287	0.285	0.285
R3VR3	0.303	0.261	0.226	0.156	0.252	0.191	0.241	0.194
R4VR4	0.297	0.236	0.233	0.158	0.258	0.202	0.248	0.200
R2VR3	0.336	0.314	0.311	0.324	0.298	0.271	0.265	0.262
R3VR4	0.296	0.245	0.228	0.157	0.250	0.190	0.243	0.196
R1F1	0.331	0.330	0.333	0.333	0.304	0.306	0.304	0.305
R1F2	0.331	0.329	0.332	0.333	0.292	0.293	0.293	0.293
R4F1	0.315	0.676	0.227	0.155	0.302	0.334	0.275	0.214
R4F2	0.323	0.750	0.225	0.162	0.303	0.368	0.245	0.182

Estimated value of the CV of first year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	9%	8%	9%	9%	9%	8%	8%	8%
R1	8%	9%	9%	8%	9%	8%	9%	8%
R2	9%	9%	9%	9%	8%	8%	8%	8%
R3	10%	12%	8%	8%	9%	11%	8%	8%
R4	9%	12%	8%	8%	9%	11%	8%	8%
R1M1	8%	8%	9%	9%	8%	8%	9%	9%
R2M1	8%	9%	9%	9%	9%	9%	9%	9%
R3M1	10%	12%	8%	8%	10%	12%	8%	8%
R4M1	10%	12%	8%	8%	10%	12%	8%	8%
R1M2	8%	8%	9%	8%	8%	8%	8%	8%
R2M2	8%	9%	9%	9%	8%	8%	8%	8%
R3M2	10%	12%	8%	8%	10%	12%	8%	8%
R4M2	10%	12%	8%	8%	10%	11%	8%	8%
R1VR1	8%	8%	9%	8%	8%	8%	9%	8%
R2VR2	8%	8%	9%	9%	9%	8%	8%	8%
R3VR3	9%	11%	8%	8%	9%	9%	8%	8%
R4VR4	9%	11%	8%	8%	9%	10%	8%	8%
R2VR3	9%	8%	8%	9%	9%	8%	8%	8%
R3VR4	9%	11%	8%	8%	9%	9%	8%	8%
R1F1	9%	9%	9%	8%	9%	8%	9%	9%
R1F2	8%	8%	9%	8%	8%	8%	9%	8%
R4F1	9%	10%	8%	9%	9%	9%	8%	8%
R4F2	10%	10%	8%	16%	9%	9%	8%	8%

Appendix E-46 Relative error of first year fishing mortality and results of the hypothesis test to determine if the estimated value of first year fishing mortality is within 10% of the true value of first year fishing mortality (sample size = 300).

Age Sample Size = 300

Relative error of first year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	1%	1%	2%	1%	1%	2%	1%	2%
R1	-2%	-2%	-2%	-2%	-15%	-15%	-15%	-15%
R2	-3%	-3%	-2%	-2%	-16%	-15%	-16%	-16%
R3	0%	-1%	-34%	-35%	0%	5%	-39%	-40%
R4	0%	-1%	-34%	-35%	0%	4%	-39%	-40%
R1M1	0%	1%	1%	1%	-8%	-8%	-8%	-8%
R2M1	2%	2%	2%	3%	-6%	-5%	-5%	-5%
R3M1	0%	-2%	-33%	-34%	1%	2%	-36%	-37%
R4M1	1%	-1%	-32%	-33%	5%	5%	-34%	-35%
R1M2	1%	0%	1%	1%	-8%	-7%	-8%	-7%
R2M2	1%	0%	1%	1%	-8%	-7%	-8%	-8%
R3M2	0%	-2%	-33%	-34%	2%	2%	-37%	-38%
R4M2	0%	-2%	-33%	-34%	2%	3%	-37%	-38%
R1VR1	-4%	-5%	-4%	-4%	-15%	-15%	-15%	-15%
R2VR2	0%	0%	1%	1%	-14%	-13%	-14%	-14%
R3VR3	-8%	-21%	-32%	-53%	-24%	-42%	-27%	-41%
R4VR4	-10%	-29%	-29%	-52%	-22%	-39%	-25%	-39%
R2VR3	2%	-5%	-6%	-2%	-10%	-18%	-20%	-21%
R3VR4	-10%	-26%	-31%	-52%	-24%	-42%	-26%	-41%
R1F1	0%	0%	1%	1%	-8%	-7%	-8%	-8%
R1F2	0%	0%	1%	1%	-12%	-11%	-11%	-11%
R4F1	-5%	105%	-31%	-53%	-8%	1%	-17%	-35%
R4F2	-2%	127%	-32%	-51%	-8%	11%	-26%	-2%

Results of testing Ho: The relative difference between the true and estimated first year fishing mortality is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject
R3VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject

Appendix E-47 Average and coefficient of variation (CV) of first year fishing mortality across 1000 replicates by reader type(s)/scenarios (sample size = 900).

Age Sample Size = 900
Estimated value of first year fishing mortality among reader(s)/scenarios.
True value of first year fishing mortality is 0.330

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.335	0.334	0.336	0.334	0.334	0.336	0.336	0.335
R1	0.325	0.324	0.326	0.324	0.279	0.281	0.281	0.281
R2	0.322	0.323	0.325	0.323	0.278	0.279	0.279	0.279
R3	0.333	0.329	0.218	0.213	0.332	0.350	0.201	0.197
R4	0.333	0.330	0.217	0.212	0.330	0.347	0.201	0.197
R1M1	0.333	0.333	0.335	0.333	0.303	0.304	0.305	0.304
R2M1	0.338	0.338	0.339	0.337	0.314	0.314	0.315	0.314
R3M1	0.330	0.325	0.223	0.217	0.336	0.342	0.213	0.209
R4M1	0.337	0.331	0.224	0.219	0.349	0.353	0.218	0.213
R1M2	0.333	0.333	0.334	0.332	0.306	0.306	0.306	0.306
R2M2	0.333	0.333	0.335	0.333	0.304	0.306	0.306	0.305
R3M2	0.332	0.325	0.223	0.217	0.338	0.342	0.209	0.204
R4M2	0.333	0.326	0.223	0.217	0.339	0.343	0.208	0.204
R1VR1	0.315	0.316	0.317	0.315	0.279	0.281	0.281	0.280
R2VR2	0.332	0.331	0.333	0.331	0.285	0.287	0.287	0.286
R3VR3	0.306	0.262	0.226	0.154	0.251	0.192	0.242	0.193
R4VR4	0.299	0.236	0.232	0.157	0.258	0.202	0.249	0.199
R2VR3	0.336	0.315	0.313	0.323	0.296	0.271	0.266	0.262
R3VR4	0.298	0.244	0.228	0.156	0.249	0.190	0.244	0.195
R1F1	0.332	0.332	0.334	0.331	0.305	0.306	0.307	0.305
R1F2	0.332	0.331	0.333	0.332	0.292	0.292	0.293	0.293
R4F1	0.318	0.681	0.227	0.153	0.301	0.335	0.277	0.213
R4F2	0.324	0.759	0.225	0.153	0.303	0.369	0.246	0.181

Estimated value of the CV of first year fishing mortality among reader(s)/scenarios.

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	8%	8%	8%	8%	8%	8%	8%	8%
R1	8%	8%	8%	8%	8%	8%	8%	8%
R2	8%	8%	8%	8%	8%	8%	8%	8%
R3	9%	11%	8%	8%	9%	11%	8%	8%
R4	9%	11%	8%	8%	9%	10%	8%	8%
R1M1	8%	8%	8%	8%	8%	8%	8%	8%
R2M1	8%	8%	8%	8%	8%	8%	8%	8%
R3M1	9%	11%	7%	8%	9%	11%	8%	8%
R4M1	9%	11%	7%	8%	9%	11%	8%	8%
R1M2	8%	8%	8%	8%	8%	8%	8%	8%
R2M2	8%	8%	8%	8%	8%	8%	8%	8%
R3M2	9%	11%	7%	8%	9%	11%	8%	8%
R4M2	9%	11%	7%	8%	9%	11%	8%	8%
R1VR1	8%	8%	8%	8%	8%	8%	8%	8%
R2VR2	8%	8%	8%	8%	8%	8%	8%	8%
R3VR3	9%	10%	8%	7%	8%	9%	8%	8%
R4VR4	9%	9%	8%	7%	8%	9%	8%	8%
R2VR3	8%	8%	8%	8%	8%	8%	8%	8%
R3VR4	8%	10%	8%	7%	8%	9%	8%	8%
R1F1	8%	8%	8%	8%	8%	8%	8%	8%
R1F2	8%	8%	8%	8%	8%	8%	8%	8%
R4F1	9%	8%	7%	7%	9%	8%	8%	8%
R4F2	8%	8%	7%	7%	8%	9%	8%	8%

Appendix E-48 Relative error of first year fishing mortality and results of the hypothesis test to determine if the estimated value of first year fishing mortality is within 10% of the true value of first year fishing mortality (sample size = 900).

Age Sample Size = 900

Relative error of first year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	1%	1%	2%	1%	1%	2%	2%	1%
R1	-2%	-2%	-1%	-2%	-15%	-15%	-15%	-15%
R2	-2%	-2%	-2%	-2%	-16%	-15%	-15%	-15%
R3	1%	0%	-34%	-35%	1%	6%	-39%	-40%
R4	1%	0%	-34%	-36%	0%	5%	-39%	-40%
R1M1	1%	1%	2%	1%	-8%	-8%	-8%	-8%
R2M1	2%	2%	3%	2%	-5%	-5%	-5%	-5%
R3M1	0%	-1%	-33%	-34%	2%	4%	-35%	-37%
R4M1	2%	0%	-32%	-34%	6%	7%	-34%	-35%
R1M2	1%	1%	1%	1%	-7%	-7%	-7%	-7%
R2M2	1%	1%	1%	1%	-8%	-7%	-7%	-8%
R3M2	1%	-1%	-33%	-34%	2%	4%	-37%	-38%
R4M2	1%	-1%	-32%	-34%	3%	4%	-37%	-38%
R1VR1	-4%	-4%	-4%	-4%	-15%	-15%	-15%	-15%
R2VR2	1%	0%	1%	0%	-14%	-13%	-13%	-13%
R3VR3	-7%	-21%	-32%	-53%	-24%	-42%	-27%	-41%
R4VR4	-9%	-28%	-30%	-52%	-22%	-39%	-24%	-40%
R2VR3	2%	-4%	-5%	-2%	-10%	-18%	-19%	-21%
R3VR4	-10%	-26%	-31%	-53%	-25%	-42%	-26%	-41%
R1F1	0%	0%	1%	0%	-8%	-7%	-7%	-8%
R1F2	1%	0%	1%	1%	-12%	-11%	-11%	-11%
R4F1	-4%	106%	-31%	-54%	-9%	2%	-16%	-35%
R4F2	-2%	130%	-32%	-54%	-8%	12%	-25%	-45%

Results of testing Ho: The relative difference between the true and estimated first year fishing mortality is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R3M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject
R3VR4	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject

Appendix E-49 Average and coefficient of variation (CV) of last year fishing mortality across 1000 replicates by reader type(s)/scenarios (sample size = 100).

Age Sample Size = 100
Estimated value of last year fishing mortality among reader(s)/scenarios.
True value of last year fishing mortality is 0.0813

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.087	0.087	0.087	0.087	0.087	0.087	0.088	0.087
R1	0.092	0.091	0.091	0.092	0.110	0.111	0.112	0.110
R2	0.093	0.092	0.092	0.093	0.112	0.112	0.112	0.111
R3	0.087	0.087	0.172	0.169	0.092	0.089	0.174	0.168
R4	0.087	0.087	0.172	0.169	0.093	0.090	0.173	0.168
R1M1	0.088	0.088	0.088	0.088	0.103	0.103	0.103	0.102
R2M1	0.088	0.087	0.087	0.087	0.101	0.101	0.102	0.101
R3M1	0.086	0.087	0.169	0.166	0.090	0.090	0.168	0.163
R4M1	0.085	0.086	0.169	0.166	0.089	0.089	0.166	0.161
R1M2	0.088	0.087	0.087	0.088	0.100	0.099	0.100	0.100
R2M2	0.088	0.088	0.088	0.088	0.100	0.101	0.101	0.100
R3M2	0.086	0.087	0.169	0.167	0.089	0.087	0.177	0.171
R4M2	0.086	0.087	0.170	0.167	0.089	0.088	0.177	0.172
R1VR1	0.093	0.093	0.093	0.093	0.110	0.110	0.111	0.110
R2VR2	0.089	0.088	0.089	0.089	0.108	0.108	0.109	0.108
R3VR3	0.094	0.103	0.159	0.269	0.121	0.155	0.134	0.170
R4VR4	0.096	0.114	0.151	0.257	0.115	0.143	0.129	0.163
R2VR3	0.090	0.095	0.094	0.092	0.103	0.115	0.118	0.119
R3VR4	0.096	0.109	0.158	0.266	0.122	0.157	0.133	0.169
R1F1	0.088	0.088	0.088	0.088	0.103	0.102	0.103	0.102
R1F2	0.088	0.088	0.088	0.088	0.103	0.103	0.103	0.102
R4F1	0.090	0.070	0.165	0.245	0.102	0.099	0.118	0.153
R4F2	0.088	0.067	0.168	0.190	0.099	0.093	0.134	0.190

Estimated value of the CV of last year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	19%	18%	17%	17%	18%	18%	18%	18%
R1	19%	18%	17%	17%	17%	17%	17%	17%
R2	19%	17%	17%	17%	17%	17%	18%	17%
R3	21%	23%	16%	16%	19%	22%	16%	16%
R4	21%	23%	16%	16%	19%	23%	16%	15%
R1M1	19%	18%	17%	17%	18%	17%	18%	18%
R2M1	19%	17%	17%	17%	18%	18%	18%	18%
R3M1	21%	23%	19%	19%	19%	23%	16%	16%
R4M1	21%	23%	18%	18%	20%	24%	16%	16%
R1M2	19%	18%	17%	17%	18%	17%	17%	17%
R2M2	19%	18%	17%	17%	17%	17%	18%	17%
R3M2	21%	23%	19%	19%	19%	23%	16%	16%
R4M2	21%	23%	18%	18%	19%	23%	16%	16%
R1VR1	19%	18%	17%	17%	17%	17%	17%	17%
R2VR2	19%	18%	17%	17%	17%	17%	18%	17%
R3VR3	20%	25%	16%	17%	18%	24%	17%	16%
R4VR4	21%	25%	16%	15%	18%	23%	17%	16%
R2VR3	19%	17%	17%	17%	17%	17%	17%	17%
R3VR4	21%	24%	16%	16%	17%	25%	17%	16%
R1F1	19%	18%	17%	18%	18%	18%	18%	18%
R1F2	19%	18%	17%	17%	17%	17%	17%	17%
R4F1	21%	20%	16%	31%	18%	18%	18%	16%
R4F2	21%	20%	17%	34%	18%	18%	16%	16%

Appendix E-50 Relative error of last year fishing mortality and results of the hypothesis test to determine if the estimated value of last year fishing mortality is within 10% of the true value of last year fishing mortality (sample size = 100).

Age Sample Size = 100
Relative error of last year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	7%	7%	7%	7%	7%	8%	8%	7%
R1	13%	12%	13%	13%	36%	36%	37%	36%
R2	14%	13%	13%	14%	37%	37%	38%	37%
R3	7%	7%	112%	108%	13%	9%	114%	107%
R4	7%	8%	111%	108%	14%	11%	113%	106%
R1M1	8%	8%	8%	8%	26%	27%	27%	26%
R2M1	8%	7%	7%	8%	24%	24%	25%	24%
R3M1	6%	7%	108%	104%	11%	11%	106%	101%
R4M1	5%	6%	108%	104%	9%	10%	104%	98%
R1M2	9%	7%	7%	8%	23%	22%	23%	23%
R2M2	8%	8%	8%	8%	23%	24%	25%	24%
R3M2	6%	7%	108%	105%	9%	8%	118%	111%
R4M2	6%	7%	109%	105%	9%	8%	117%	111%
R1VR1	15%	14%	14%	14%	35%	35%	36%	35%
R2VR2	9%	9%	9%	9%	33%	33%	34%	32%
R3VR3	16%	27%	96%	230%	49%	91%	65%	109%
R4VR4	18%	40%	86%	216%	41%	76%	59%	100%
R2VR3	10%	17%	16%	13%	27%	41%	46%	46%
R3VR4	18%	35%	94%	227%	50%	93%	64%	107%
R1F1	9%	9%	8%	8%	26%	26%	27%	26%
R1F2	8%	8%	8%	8%	27%	26%	27%	26%
R4F1	10%	-13%	103%	201%	25%	22%	45%	88%
R4F2	8%	-17%	107%	134%	22%	14%	65%	134%

Results of testing Ho: The relative difference between the true and estimated last year fishing mortality is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R3	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject

Appendix E-51 Average and coefficient of variation (CV) of last year fishing mortality across 1000 replicates by reader type(s)/scenarios (sample size = 300).

Age Sample Size = 300
Estimated value of last year fishing mortality among reader(s)/scenarios.
True value of last year fishing mortality is 0.0813

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.085	0.085	0.086	0.086	0.085	0.086	0.086	0.086
R1	0.089	0.089	0.090	0.090	0.108	0.109	0.109	0.109
R2	0.090	0.090	0.091	0.091	0.109	0.110	0.110	0.110
R3	0.084	0.082	0.171	0.169	0.089	0.086	0.172	0.169
R4	0.084	0.083	0.171	0.168	0.091	0.087	0.171	0.169
R1M1	0.08[illegible]	0.086	0.087	0.087	0.100	0.101	0.100	0.101
R2M1	0.085	0.085	0.086	0.086	0.097	0.099	0.098	0.098
R3M1	0.083	0.082	0.171	0.170	0.088	0.086	0.166	0.164
R4M1	0.082	0.082	0.171	0.168	0.085	0.085	0.163	0.161
R1M2	0.086	0.085	0.087	0.087	0.097	0.098	0.098	0.098
R2M2	0.086	0.086	0.087	0.087	0.098	0.099	0.099	0.099
R3M2	0.083	0.082	0.171	0.170	0.086	0.084	0.174	0.172
R4M2	0.083	0.082	0.171	0.170	0.086	0.085	0.174	0.172
R1VR1	0.091	0.091	0.092	0.092	0.108	0.109	0.108	0.109
R2VR2	0.087	0.086	0.087	0.087	0.105	0.107	0.106	0.107
R3VR3	0.091	0.098	0.159	0.274	0.119	0.152	0.132	0.171
R4VR4	0.093	0.110	0.151	0.258	0.112	0.140	0.127	0.163
R2VR3	0.087	0.092	0.093	0.090	0.101	0.113	0.116	0.118
R3VR4	0.093	0.105	0.157	0.268	0.120	0.155	0.131	0.169
R1F1	0.086	0.086	0.087	0.087	0.100	0.101	0.100	0.101
R1F2	0.086	0.086	0.087	0.087	0.101	0.102	0.102	0.102
R4F1	0.087	0.068	0.164	0.293	0.098	0.097	0.114	0.151
R4F2	0.085	0.064	0.167	0.285	0.096	0.091	0.132	0.190

Estimated value of the CV of last year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	17%	15%	16%	17%	16%	16%	16%	16%
R1	16%	16%	16%	17%	16%	16%	15%	16%
R2	17%	16%	16%	17%	15%	16%	15%	15%
R3	17%	18%	15%	15%	16%	20%	14%	15%
R4	18%	18%	15%	15%	16%	19%	15%	15%
R1M1	17%	15%	16%	17%	16%	16%	16%	16%
R2M1	17%	16%	16%	17%	16%	16%	15%	16%
R3M1	18%	19%	15%	16%	17%	20%	14%	15%
R4M1	17%	19%	15%	16%	17%	21%	15%	15%
R1M2	17%	16%	16%	17%	15%	16%	15%	15%
R2M2	16%	16%	16%	17%	15%	16%	15%	15%
R3M2	18%	19%	15%	16%	17%	20%	14%	15%
R4M2	18%	19%	15%	16%	16%	19%	15%	15%
R1VR1	16%	16%	16%	17%	15%	16%	15%	16%
R2VR2	16%	15%	16%	17%	16%	15%	15%	16%
R3VR3	17%	19%	15%	15%	16%	20%	15%	15%
R4VR4	17%	20%	15%	15%	16%	20%	15%	15%
R2VR3	16%	15%	16%	17%	16%	16%	15%	15%
R3VR4	17%	19%	15%	15%	16%	21%	15%	15%
R1F1	16%	16%	16%	17%	16%	16%	16%	16%
R1F2	17%	15%	16%	17%	15%	16%	15%	15%
R4F1	17%	17%	15%	15%	16%	16%	15%	15%
R4F2	17%	16%	15%	22%	16%	17%	15%	15%

Appendix E-52 Relative error of last year fishing mortality and results of the hypothesis test to determine if the estimated value of last year fishing mortality is within 10% of the true value of last year fishing mortality (sample size = 300).

Age Sample Size = 300
Relative error of last year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	5%	5%	6%	6%	5%	6%	6%	6%
R1	10%	9%	10%	11%	33%	34%	34%	35%
R2	10%	11%	11%	12%	34%	36%	35%	36%
R3	3%	1%	110%	108%	10%	5%	111%	108%
R4	4%	2%	110%	107%	11%	7%	110%	107%
R1M1	6%	5%	7%	7%	23%	24%	23%	24%
R2M1	5%	4%	5%	6%	20%	22%	21%	21%
R3M1	2%	1%	111%	109%	8%	6%	104%	101%
R4M1	1%	0%	111%	107%	5%	5%	100%	98%
R1M2	6%	5%	7%	7%	19%	21%	20%	21%
R2M2	6%	5%	7%	7%	21%	22%	21%	21%
R3M2	2%	1%	111%	109%	5%	4%	114%	112%
R4M2	2%	1%	111%	109%	6%	5%	115%	112%
R1VR1	12%	12%	13%	13%	33%	34%	33%	34%
R2VR2	7%	6%	7%	7%	29%	31%	30%	31%
R3VR3	12%	21%	96%	237%	46%	87%	62%	110%
R4VR4	14%	35%	85%	218%	38%	72%	56%	101%
R2VR3	7%	13%	14%	11%	24%	39%	43%	45%
R3VR4	14%	29%	93%	230%	47%	90%	62%	108%
R1F1	6%	6%	7%	7%	22%	24%	23%	24%
R1F2	6%	5%	7%	7%	24%	25%	25%	26%
R4F1	6%	-17%	102%	261%	21%	20%	41%	86%
R4F2	4%	-21%	106%	251%	18%	12%	63%	4%

Results of testing Ho: The relative difference between the true and estimated last year fishing mortality is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject
R3	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject

Appendix E-53 Average and coefficient of variation (CV) of last year fishing mortality across 1000 replicates by reader type(s)/scenarios (sample size = 900).

Age Sample Size = 900
Estimated value of last year fishing mortality among reader(s)/scenarios.
True value of last year fishing mortality is 0.0813

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.085	0.085	0.085	0.084	0.085	0.085	0.085	0.085
R1	0.089	0.089	0.089	0.088	0.108	0.108	0.109	0.108
R2	0.089	0.090	0.089	0.088	0.109	0.109	0.109	0.108
R3	0.083	0.082	0.170	0.167	0.089	0.084	0.172	0.168
R4	0.083	0.083	0.170	0.166	0.090	0.085	0.172	0.166
R1M1	0.085	0.086	0.086	0.085	0.099	0.100	0.099	0.099
R2M1	0.085	0.085	0.085	0.084	0.097	0.097	0.098	0.097
R3M1	0.082	0.082	0.170	0.167	0.086	0.084	0.165	0.161
R4M1	0.081	0.081	0.170	0.166	0.084	0.083	0.162	0.159
R1M2	0.085	0.085	0.086	0.084	0.097	0.097	0.097	0.096
R2M2	0.085	0.086	0.086	0.085	0.098	0.098	0.098	0.097
R3M2	0.082	0.082	0.170	0.167	0.085	0.083	0.174	0.171
R4M2	0.082	0.082	0.171	0.167	0.085	0.083	0.175	0.170
R1VR1	0.090	0.091	0.091	0.090	0.107	0.108	0.108	0.107
R2VR2	0.086	0.086	0.086	0.085	0.105	0.105	0.106	0.105
R3VR3	0.090	0.098	0.158	0.268	0.118	0.151	0.131	0.169
R4VR4	0.092	0.109	0.150	0.254	0.112	0.138	0.126	0.161
R2VR3	0.086	0.092	0.092	0.088	0.100	0.112	0.116	0.116
R3VR4	0.092	0.105	0.156	0.263	0.119	0.152	0.131	0.167
R1F1	0.086	0.086	0.086	0.085	0.098	0.099	0.100	0.099
R1F2	0.086	0.085	0.086	0.085	0.100	0.101	0.101	0.100
R4F1	0.086	0.068	0.163	0.291	0.097	0.096	0.113	0.149
R4F2	0.084	0.065	0.167	0.300	0.095	0.090	0.131	0.187

Estimated value of the CV of last year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	16%	17%	16%	15%	16%	16%	16%	16%
R1	15%	16%	15%	15%	15%	16%	16%	15%
R2	15%	16%	15%	15%	16%	16%	15%	15%
R3	16%	21%	15%	14%	16%	19%	15%	15%
R4	16%	21%	14%	14%	17%	19%	15%	15%
R1M1	16%	17%	16%	15%	16%	16%	16%	15%
R2M1	15%	17%	16%	15%	16%	16%	16%	16%
R3M1	17%	21%	15%	14%	17%	19%	15%	15%
R4M1	16%	21%	14%	14%	17%	20%	15%	15%
R1M2	16%	17%	15%	15%	16%	16%	16%	15%
R2M2	16%	17%	15%	15%	16%	16%	15%	15%
R3M2	16%	21%	15%	14%	16%	19%	15%	15%
R4M2	17%	22%	14%	14%	17%	20%	15%	15%
R1VR1	15%	17%	15%	15%	15%	16%	15%	15%
R2VR2	16%	17%	15%	15%	16%	16%	16%	15%
R3VR3	16%	21%	15%	14%	16%	20%	15%	15%
R4VR4	16%	21%	15%	14%	16%	19%	15%	14%
R2VR3	15%	17%	15%	15%	16%	16%	15%	15%
R3VR4	16%	21%	15%	14%	16%	20%	15%	15%
R1F1	16%	17%	16%	15%	16%	16%	16%	16%
R1F2	15%	17%	15%	15%	15%	15%	16%	15%
R4F1	16%	19%	14%	14%	16%	16%	16%	15%
R4F2	16%	19%	15%	13%	16%	16%	15%	14%

Appendix E-54 Relative error of last year fishing mortality and results of the hypothesis test to determine if the estimated value of last year fishing mortality is within 10% of the true value of last year fishing mortality (sample size = 900).

Age Sample Size = 900
Relative error of last year fishing mortality among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	4%	4%	5%	3%	4%	5%	5%	4%
R1	9%	9%	9%	8%	32%	33%	33%	32%
R2	10%	10%	10%	9%	34%	34%	34%	33%
R3	2%	1%	109%	105%	9%	4%	111%	106%
R4	2%	2%	109%	104%	10%	5%	111%	105%
R1M1	5%	5%	6%	4%	21%	22%	22%	21%
R2M1	4%	4%	4%	3%	19%	20%	20%	19%
R3M1	1%	1%	110%	105%	6%	4%	103%	98%
R4M1	0%	0%	109%	104%	4%	2%	99%	95%
R1M2	5%	5%	5%	4%	19%	19%	19%	19%
R2M2	5%	6%	6%	5%	20%	20%	21%	19%
R3M2	1%	1%	110%	106%	5%	2%	114%	110%
R4M2	1%	1%	110%	105%	5%	2%	115%	109%
R1VR1	11%	11%	12%	10%	32%	33%	32%	31%
R2VR2	6%	6%	6%	4%	29%	30%	30%	29%
R3VR3	11%	21%	95%	229%	46%	86%	61%	107%
R4VR4	13%	34%	84%	213%	38%	70%	55%	98%
R2VR3	6%	13%	13%	8%	24%	37%	42%	42%
R3VR4	13%	29%	92%	224%	46%	87%	61%	105%
R1F1	6%	6%	6%	5%	21%	22%	22%	21%
R1F2	5%	5%	6%	4%	23%	24%	24%	23%
R4F1	5%	-17%	100%	258%	20%	18%	40%	83%
R4F2	3%	-21%	105%	268%	17%	10%	62%	130%

Results of testing Ho: The relative difference between the true and estimated last year fishing mortality is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M1	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R4M2	Fail to Reject	Fail to Reject	Reject	Reject	Fail to Reject	Fail to Reject	Reject	Reject
R1VR1	Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR3	Fail to Reject	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Fail to Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R4F2	Fail to Reject	Reject	Reject	Reject	Reject	Fail to Reject	Reject	Reject

Appendix E-55 Average and coefficient of variation (CV) of selectivity of age 2 fish across 1000 replicates by reader type(s)/scenarios (sample size = 100).

Age Sample Size = 100
Estimated value of selectivity of age 2 among reader(s)/scenarios.
True value of selectivity of age 2 is 0.187

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.240	0.235	0.235	0.243	0.231	0.233	0.232	0.239
R1	0.223	0.223	0.225	0.225	0.356	0.357	0.355	0.359
R2	0.228	0.228	0.229	0.231	0.367	0.368	0.364	0.368
R3	1.228	2.370	a	a	1.092	2.233	a	a
R4	1.226	2.394	a	a	1.102	2.259	a	a
R1M1	0.234	0.232	0.229	0.234	0.334	0.335	0.335	0.336
R2M1	0.228	0.218	0.225	0.226	0.345	0.347	0.342	0.344
R3M1	1.259	2.390	a	a	1.205	2.417	a	a
R4M1	1.257	2.410	a	a	1.221	2.483	a	a
R1M2	0.232	0.230	0.226	0.232	0.255	0.256	0.255	0.257
R2M2	0.226	0.216	0.223	0.224	0.259	0.262	0.258	0.261
R3M2	1.256	2.386	a	a	1.125	2.316	a	a
R4M2	1.254	2.395	a	a	1.124	2.322	a	a
R1VR1	0.237	0.242	0.235	0.237	0.148	0.150	0.161	0.150
R2VR2	0.219	0.224	0.220	0.226	0.344	0.346	0.343	0.346
R3VR3	1.211	2.738	a	a	0.989	3.140	a	a
R4VR4	1.221	3.023	a	a	1.026	2.998	a	a
R2VR3	0.260	0.278	0.232	0.224	0.513	0.637	0.211	0.314
R3VR4	1.223	2.910	a	a	0.990	3.151	a	a
R1F1	0.245	0.241	0.239	0.248	0.267	0.272	0.263	0.255
R1F2	0.241	0.237	0.235	0.244	0.201	0.207	0.199	0.189
R4F1	1.244	0.411	a	a	0.768	0.703	a	a
R4F2	1.239	0.390	a	a	0.749	0.624	a	a

Estimated value of the CV of selectivity of age 2 among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	82%	79%	80%	83%	78%	77%	78%	80%
R1	29%	29%	33%	33%	13%	13%	13%	14%
R2	21%	22%	24%	26%	13%	13%	13%	14%
R3	10%	11%	a	a	11%	11%	a	a
R4	11%	11%	a	a	11%	11%	a	a
R1M1	74%	72%	70%	74%	15%	15%	15%	15%
R2M1	68%	58%	66%	66%	15%	15%	15%	15%
R3M1	11%	11%	a	a	12%	12%	a	a
R4M1	11%	11%	a	a	12%	12%	a	a
R1M2	75%	73%	71%	75%	15%	15%	15%	15%
R2M2	69%	59%	67%	67%	14%	15%	15%	15%
R3M2	11%	11%	a	a	11%	11%	a	a
R4M2	11%	11%	a	a	11%	11%	a	a
R1VR1	88%	88%	86%	87%	68%	72%	90%	72%
R2VR2	58%	63%	60%	65%	13%	14%	13%	14%
R3VR3	11%	10%	a	a	11%	10%	a	a
R4VR4	11%	11%	a	a	11%	10%	a	a
R2VR3	14%	15%	82%	33%	12%	11%	16%	15%
R3VR4	11%	10%	a	a	11%	10%	a	a
R1F1	82%	79%	79%	82%	85%	87%	86%	84%
R1F2	83%	81%	81%	84%	122%	123%	123%	121%
R4F1	11%	11%	a	a	13%	12%	a	a
R4F2	11%	11%	a	a	12%	11%	a	a

[a] The selectivity of age 2 fish was not estimated among some or all of these simulation runs.

Appendix E-56 Relative error of selectivity of age 2 fish and results of the hypothesis test to determine if the estimated value of selectivity of age 2 fish is within 10% of the true value of selectivity of age 2 fish (sample size = 100).

Age Sample Size = 100
Relative error of selectivity of age 2 among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	29%	26%	26%	30%	23%	25%	24%	28%
R1	19%	20%	20%	20%	90%	91%	90%	92%
R2	22%	22%	22%	23%	97%	97%	95%	97%
R3	557%	1167%	a	a	484%	1094%	a	a
R4	556%	1180%	a	a	489%	1108%	a	a
R1M1	25%	24%	22%	25%	79%	79%	79%	80%
R2M1	22%	17%	21%	21%	84%	86%	83%	84%
R3M1	573%	1178%	a	a	544%	1193%	a	a
R4M1	572%	1189%	a	a	553%	1228%	a	a
R1M2	24%	23%	21%	24%	36%	37%	37%	37%
R2M2	21%	15%	19%	20%	39%	40%	38%	39%
R3M2	572%	1176%	a	a	501%	1139%	a	a
R4M2	571%	1181%	a	a	501%	1142%	a	a
R1VR1	27%	29%	25%	27%	-21%	-20%	-14%	-20%
R2VR2	17%	20%	18%	21%	84%	85%	83%	85%
R3VR3	547%	1364%	a	a	429%	1579%	a	a
R4VR4	553%	1517%	a	a	449%	1503%	a	a
R2VR3	39%	49%	24%	20%	174%	241%	13%	68%
R3VR4	554%	1456%	a	a	429%	1585%	a	a
R1F1	31%	29%	28%	33%	43%	46%	41%	36%
R1F2	29%	27%	26%	31%	8%	11%	6%	1%
R4F1	565%	120%	a	a	311%	276%	a	a
R4F2	563%	108%	a	a	301%	234%	a	a

Results of testing Ho: The relative difference between the true and estimated selectivity of age 2 is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	a	a	Reject	Reject	a	a
R4	Reject	Reject	a	a	Reject	Reject	a	a
R1M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2M1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R3M1	Reject	Reject	a	a	Reject	Reject	a	a
R4M1	Reject	Reject	a	a	Reject	Reject	a	a
R1M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2M2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R3M2	Reject	Reject	a	a	Reject	Reject	a	a
R4M2	Reject	Reject	a	a	Reject	Reject	a	a
R1VR1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2VR2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	a	a	Reject	Reject	a	a
R4VR4	Reject	Reject	a	a	Reject	Reject	a	a
R2VR3	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	a	a	Reject	Reject	a	a
R1F1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R1F2	Reject	Reject	Reject	Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R4F1	Reject	Reject	a	a	Reject	Reject	a	a
R4F2	Reject	Reject	a	a	Reject	Reject	a	a

[a] The selectivity of age 2 fish was not estimated among some or all of these simulation runs.

Appendix E-57 Average and coefficient of variation (CV) of selectivity of age 2 fish across 1000 replicates by reader type(s)/scenarios (sample size = 300).

Age Sample Size = 300
Estimated value of selectivity of age 2 among reader(s)/scenarios.
True value of selectivity of age 2 is 0.187

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.189	0.189	0.189	0.189	0.188	0.190	0.189	0.189
R1	0.217	0.217	0.217	0.216	0.354	0.354	0.354	0.354
R2	0.225	0.226	0.226	0.225	0.365	0.364	0.364	0.367
R3	1.227	2.338	a	a	1.089	2.212	a	a
R4	1.226	2.365	a	a	1.103	2.245	a	a
R1M1	0.195	0.194	0.195	0.194	0.331	0.332	0.331	0.332
R2M1	0.197	0.196	0.197	0.196	0.340	0.340	0.340	0.340
R3M1	1.258	2.358	a	a	1.206	2.395	a	a
R4M1	1.256	2.379	a	a	1.211	2.463	a	a
R1M2	0.193	0.192	0.193	0.192	0.252	0.253	0.253	0.253
R2M2	0.195	0.194	0.195	0.194	0.257	0.257	0.257	0.257
R3M2	1.255	2.355	a	a	1.124	2.295	a	a
R4M2	1.253	2.365	a	a	1.118	2.315	a	a
R1VR1	0.181	0.180	0.182	0.180	0.134	0.134	0.133	0.134
R2VR2	0.198	0.197	0.198	0.197	0.341	0.342	0.341	0.342
R3VR3	1.211	2.724	a	a	0.987	3.164	a	a
R4VR4	1.225	3.024	a	a	1.025	3.020	a	a
R2VR3	0.258	0.276	0.184	0.215	0.508	0.635	0.209	0.310
R3VR4	1.226	2.904	a	a	0.990	3.177	a	a
R1F1	0.192	0.192	0.192	0.191	0.191	0.192	0.192	0.192
R1F2	0.188	0.187	0.188	0.187	0.122	0.123	0.123	0.122
R4F1	1.244	0.407	a	a	0.766	0.698	a	a
R4F2	1.239	0.385	a	a	0.746	0.621	a	a

Estimated value of the CV of selectivity of age 2 among reader(s)/scenarios.

Reader(s)/Scenario	High Precision				Low Precision			
	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	10%	9%	9%	10%	17%	16%	16%	10%
R1	9%	9%	9%	9%	9%	8%	8%	8%
R2	9%	9%	9%	9%	8%	8%	8%	8%
R3	7%	8%	a	a	7%	8%	a	a
R4	7%	8%	a	a	7%	7%	a	a
R1M1	10%	9%	9%	10%	9%	9%	9%	9%
R2M1	10%	9%	9%	10%	9%	9%	9%	9%
R3M1	7%	8%	a	a	8%	8%	a	a
R4M1	7%	8%	a	a	8%	8%	a	a
R1M2	10%	9%	9%	10%	9%	9%	9%	9%
R2M2	9%	9%	9%	10%	9%	9%	9%	9%
R3M2	7%	8%	a	a	7%	8%	a	a
R4M2	7%	8%	a	a	7%	8%	a	a
R1VR1	10%	10%	17%	10%	11%	11%	12%	12%
R2VR2	10%	9%	9%	10%	9%	8%	8%	8%
R3VR3	7%	7%	a	a	7%	7%	a	a
R4VR4	7%	8%	a	a	7%	7%	a	a
R2VR3	9%	8%	10%	9%	8%	7%	10%	9%
R3VR4	7%	8%	a	a	7%	7%	a	a
R1F1	10%	9%	9%	10%	11%	12%	12%	12%
R1F2	10%	9%	9%	10%	11%	12%	12%	12%
R4F1	7%	7%	a	a	8%	7%	a	a
R4F2	7%	7%	a	a	7%	7%	a	a

[a] The selectivity of age 2 fish was not estimated among some or all of these simulation runs.

Appendix E-58 Relative error of selectivity of age 2 fish and results of the hypothesis test to determine if the estimated value of selectivity of age 2 fish is within 10% of the true value of selectivity of age 2 fish (sample size = 300).

Age Sample Size = 300
Relative error of selectivity of age 2 among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	1%	1%	1%	1%	1%	1%	1%	1%
R1	16%	16%	16%	16%	89%	89%	89%	90%
R2	20%	21%	21%	20%	95%	95%	95%	96%
R3	556%	1150%	a	a	482%	1083%	a	a
R4	555%	1165%	a	a	490%	1101%	a	a
R1M1	4%	4%	4%	4%	77%	78%	77%	78%
R2M1	5%	5%	5%	5%	82%	82%	82%	82%
R3M1	573%	1161%	a	a	545%	1181%	a	a
R4M1	571%	1172%	a	a	548%	1217%	a	a
R1M2	3%	3%	3%	3%	35%	35%	35%	35%
R2M2	4%	4%	4%	4%	37%	37%	37%	37%
R3M2	571%	1159%	a	a	501%	1127%	a	a
R4M2	570%	1165%	a	a	498%	1138%	a	a
R1VR1	-3%	-4%	-3%	-4%	-28%	-29%	-29%	-29%
R2VR2	6%	6%	6%	6%	82%	83%	83%	83%
R3VR3	547%	1357%	a	a	428%	1592%	a	a
R4VR4	555%	1517%	a	a	448%	1515%	a	a
R2VR3	38%	48%	-1%	15%	172%	240%	12%	66%
R3VR4	556%	1453%	a	a	430%	1599%	a	a
R1F1	3%	2%	3%	2%	2%	3%	3%	2%
R1F2	1%	0%	1%	0%	-35%	-34%	-34%	-35%
R4F1	565%	118%	a	a	310%	273%	a	a
R4F2	562%	106%	a	a	299%	232%	a	a

Results of testing Ho: The relative difference between the true and estimated selectivity of age 2 is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	a	a	Reject	Reject	a	a
R4	Reject	Reject	a	a	Reject	Reject	a	a
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M1	Reject	Reject	a	a	Reject	Reject	a	a
R4M1	Reject	Reject	a	a	Reject	Reject	a	a
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M2	Reject	Reject	a	a	Reject	Reject	a	a
R4M2	Reject	Reject	a	a	Reject	Reject	a	a
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	a	a	Reject	Reject	a	a
R4VR4	Reject	Reject	a	a	Reject	Reject	a	a
R2VR3	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	a	a	Reject	Reject	a	a
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	a	a	Reject	Reject	a	a
R4F2	Reject	Reject	a	a	Reject	Reject	a	a

[a] The selectivity of age 2 fish was not estimated among some or all of these simulation runs.

Appendix E-59 Average and coefficient of variation (CV) of selectivity of age 2 fish across 1000 replicates by reader type(s)/scenarios (sample size = 900).

Age Sample Size = 900
Estimated value of selectivity of age 2 among reader(s)/scenarios.
True value of selectivity of age 2 is 0.187

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0.188	0.187	0.187	0.187	0.188	0.188	0.188	0.187
R1	0.217	0.216	0.215	0.216	0.353	0.354	0.354	0.354
R2	0.225	0.224	0.223	0.223	0.364	0.364	0.364	0.364
R3	1.219	2.335	a	a	1.089	2.200	a	a
R4	1.218	2.360	a	a	1.100	2.229	a	a
R1M1	0.193	0.193	0.193	0.193	0.331	0.331	0.331	0.330
R2M1	0.196	0.195	0.195	0.195	0.340	0.339	0.340	0.339
R3M1	1.250	2.353	a	a	1.202	2.370	a	a
R4M1	1.249	2.373	a	a	1.213	2.441	a	a
R1M2	0.191	0.191	0.190	0.191	0.252	0.252	0.252	0.252
R2M2	0.194	0.193	0.193	0.193	0.256	0.256	0.256	0.256
R3M2	1.247	2.352	a	a	1.122	2.276	a	a
R4M2	1.247	2.360	a	a	1.120	2.293	a	a
R1VR1	0.180	0.179	0.178	0.179	0.133	0.133	0.133	0.133
R2VR2	0.197	0.196	0.196	0.196	0.342	0.342	0.341	0.341
R3VR3	1.204	2.728	a	a	0.990	3.161	a	a
R4VR4	1.219	3.020	a	a	1.028	3.018	a	a
R2VR3	0.257	0.275	0.182	0.214	0.508	0.636	0.209	0.308
R3VR4	1.220	2.909	a	a	0.992	3.183	a	a
R1F1	0.191	0.190	0.190	0.190	0.190	0.191	0.190	0.191
R1F2	0.187	0.186	0.186	0.186	0.121	0.122	0.121	0.122
R4F1	1.238	0.405	a	a	0.768	0.696	a	a
R4F2	1.234	0.382	a	a	0.747	0.618	a	a

Estimated value of the CV of selectivity of age 2 among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	6%	6%	6%	6%	6%	6%	6%	6%
R1	6%	6%	6%	6%	5%	5%	5%	5%
R2	6%	6%	6%	6%	5%	5%	5%	5%
R3	5%	7%	a	a	5%	7%	a	a
R4	5%	7%	a	a	5%	6%	a	a
R1M1	6%	6%	6%	6%	6%	6%	6%	6%
R2M1	6%	6%	6%	6%	6%	6%	6%	6%
R3M1	5%	7%	a	a	5%	7%	a	a
R4M1	5%	7%	a	a	5%	7%	a	a
R1M2	6%	6%	6%	6%	6%	6%	6%	6%
R2M2	6%	6%	6%	6%	6%	6%	6%	6%
R3M2	5%	7%	a	a	5%	7%	a	a
R4M2	5%	7%	a	a	5%	7%	a	a
R1VR1	6%	6%	6%	6%	7%	7%	7%	7%
R2VR2	6%	6%	6%	6%	5%	5%	5%	5%
R3VR3	5%	6%	a	a	5%	6%	a	a
R4VR4	5%	6%	a	a	5%	6%	a	a
R2VR3	5%	6%	6%	6%	5%	5%	6%	6%
R3VR4	5%	6%	a	a	5%	6%	a	a
R1F1	6%	6%	6%	6%	7%	7%	7%	8%
R1F2	6%	6%	6%	6%	7%	7%	7%	8%
R4F1	5%	5%	a	a	5%	5%	a	a
R4F2	5%	5%	a	a	5%	5%	a	a

[a] The selectivity of age 2 fish was not estimated among some or all of these simulation runs.

Appendix E-60 Relative error of selectivity of age 2 fish and results of the hypothesis test to determine if the estimated value of selectivity of age 2 fish is within 10% of the true value of selectivity of age 2 fish (sample size = 900).

Age Sample Size = 900
Relative error of selectivity of age 2 among reader(s)/scenarios.

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	0%	0%	0%	0%	0%	0%	0%	0%
R1	16%	15%	15%	15%	89%	89%	89%	89%
R2	20%	20%	19%	20%	95%	95%	95%	95%
R3	552%	1149%	a	a	482%	1076%	a	a
R4	551%	1162%	a	a	488%	1092%	a	a
R1M1	3%	3%	3%	3%	77%	77%	77%	76%
R2M1	5%	5%	4%	4%	82%	81%	82%	81%
R3M1	569%	1158%	a	a	543%	1168%	a	a
R4M1	568%	1169%	a	a	549%	1205%	a	a
R1M2	2%	2%	2%	2%	35%	35%	35%	35%
R2M2	4%	3%	3%	3%	37%	37%	37%	37%
R3M2	567%	1157%	a	a	500%	1117%	a	a
R4M2	567%	1162%	a	a	499%	1126%	a	a
R1VR1	-4%	-4%	-5%	-4%	-29%	-29%	-29%	-29%
R2VR2	5%	5%	5%	5%	83%	83%	82%	83%
R3VR3	544%	1359%	a	a	429%	1591%	a	a
R4VR4	552%	1515%	a	a	450%	1514%	a	a
R2VR3	37%	47%	-3%	15%	172%	240%	12%	65%
R3VR4	552%	1456%	a	a	430%	1602%	a	a
R1F1	2%	2%	2%	2%	2%	2%	2%	2%
R1F2	0%	0%	-1%	0%	-35%	-35%	-35%	-35%
R4F1	562%	116%	a	a	311%	272%	a	a
R4F2	560%	104%	a	a	300%	231%	a	a

Results of testing Ho: The relative difference between the true and estimated selectivity of age 2 is less than the differential.
Differential= 10%

	High Precision				Low Precision			
Reader(s)/Scenario	Bias=-1	Bias=-2	Bias=1	Bias=2	Bias=-1	Bias=-2	Bias=1	Bias=2
R0	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R2	Reject	Reject	Reject	Reject	Reject	Reject	Reject	Reject
R3	Reject	Reject	a	a	Reject	Reject	a	a
R4	Reject	Reject	a	a	Reject	Reject	a	a
R1M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M1	Reject	Reject	a	a	Reject	Reject	a	a
R4M1	Reject	Reject	a	a	Reject	Reject	a	a
R1M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2M2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3M2	Reject	Reject	a	a	Reject	Reject	a	a
R4M2	Reject	Reject	a	a	Reject	Reject	a	a
R1VR1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R2VR2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R3VR3	Reject	Reject	a	a	Reject	Reject	a	a
R4VR4	Reject	Reject	a	a	Reject	Reject	a	a
R2VR3	Reject	Reject	Fail to Reject	Reject	Reject	Reject	Reject	Reject
R3VR4	Reject	Reject	a	a	Reject	Reject	a	a
R1F1	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject
R1F2	Fail to Reject	Fail to Reject	Fail to Reject	Fail to Reject	Reject	Reject	Reject	Reject
R4F1	Reject	Reject	a	a	Reject	Reject	a	a
R4F2	Reject	Reject	a	a	Reject	Reject	a	a

[a] The selectivity of age 2 fish was not estimated among some or all of these simulation runs.